

1800

A
COMPLETE TREATISE
ON
ELECTRICITY,
IN
THEORY AND PRACTICE;
WITH
ORIGINAL EXPERIMENTS.

By TIBERIUS CAVALLO, F.R.S.

THE SECOND EDITION,
With considerable ADDITIONS and ALTERATIONS.

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TO
WILLIAM WATSON,
M. D. F. R. S. M. Br. Cur.

THIS
TREATISE
OF
ELECTRICITY
IS,

WITH THE GREATEST RESPECT,

INSCRIBED

BY HIS

MOST OBEDIENT,

AND MOST HUMBLE SERVANT,

TIBERIUS CAVALLLO.

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THE
P R E F A C E.

THE design of the following Treatise is, to present to the public a comprehensive view of the present state of Electricity, reduced into as small a compass as the nature of the science would admit. It is divided into four parts, in each of which are contained such particulars, as had less connection with the rest; and the distinct view of which, it was thought, might be a means of preventing a confusion of ideas in the minds of those readers, who

before have not been much conversant with the subject.

The first part treats of the laws of Electricity only; *i. e.* of such natural laws concerning Electricity, as by innumerable experiments, have been found uniformly true, and are independent on any hypothesis. In this part, the Author has not descended to any particulars, which were not clearly ascertained, or which were inconsiderable; but he has, at the same time, taken care not to omit any thing material, or which seemed to promise future discoveries.

The second part is merely hypothetical; relating not to facts, but to opinions. The great improbability of most of these hypotheses determined

determined the Author to render this part of his work as short as possible.

The third part contains the practical branch of Electricity. Here the Author has taken care to insert a description of all the new improvements in the apparatus ; which serve to lessen the expence of it, and at the same time, to facilitate the performance of the experiments. As to the experiments themselves, he has chiefly insisted on a few principal ones, which seemed most necessary to illustrate and confirm the laws of Electricity ; omitting a great number of others, which he has met with, as they appeared to be only variations of the former. He has however given an account of some others, which, though not ab-

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solutely necessary, seemed very deserving of notice.

The fourth and last part contains a brief account of the principal experiments, which have been made by the Author himself, in pursuance of what occurred to him in the course of his studies in this branch of philosophy. In this part he has omitted to mention, not only those attempts, which did not produce any considerable effect, but also the innumerable conjectures he formed about them and others, not yet brought to the test of actual observation.

The Author takes this opportunity of acknowledging the obligations he is under to several of his ingenious friends, for various experiments,

riments, and remarks, communicated by them ; and particularly to the late Mr. WILLIAM HENLY, who did as much as laid in his power to inform him of every particular, which he thought would enrich and embellish the work.

It was deemed unnecessary to point out those gentlemen, whose experiments and observations introduced in this work, were before well known to the world ; for which reason the Author has confined himself to the mention of the names of those persons, whose experiments were new, or not commonly noticed by the writers on this subject.

This second edition, besides various additions dispersed throughout

out the work, is enriched by an Appendix, containing various interesting particulars relating to Electricity.

To render the Treatise more intelligible and useful, four copper-plates are added to it; and a copious index of the particulars which are most deserving of attention.

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INTRODUCTION.

INTRODUCTION.

A R T S and science, like kingdoms and nations, have each in their turn some happy period of glory and splendor, in which they more than ever attract the human attention, and, by casting a stronger light than at other times, become the favourite object and pursuit of the age ; but these periods are soon over, and a few years of lustre and fame are often overbalanced by centuries of oblivion. From undergoing this fate, some sciences are, however, excepted, which, owing to the vast and necessary extent of their use, and to the fruitfulness of their productions, are ever flourishing ; and although once unknown, yet when fame had proclaimed their birth, or published their advancement, they never afterwards declined. Of this kind is Electricity, one of the most pleasing and
a surprising

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surprising among all the branches of natural philosophy that ever were cultivated by man. This science, after it began to shew the extent and generality of its power; after it was known to be one of the greatest agents of nature; remained always in vogue, was profitably cultivated, irremittably advanced, and is now brought to a state, in which, instead of becoming sterile, it seems further to engage the general attention, and to promise to its followers more munificent rewards. Optics, indeed, shews many enchanting and useful properties, but concerning vision only; Magnetism exhibits the force of attraction, repulsion, and polarity in that substance called a Magnet: but Electricity, containing, as it were, all within its power, alone exhibits the effects of many sciences, combines together different powers, and, by striking the senses in a particular and surprising manner, affords pleasure, and is of use to the ignorant as well as the philosopher, the rich as well as the poor. In Electricity, we are pleased with beholding its penetrating light, exhibited in numberless different forms; we admire its attraction

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tion and repulsion, acting upon every kind of body; we are surpris'd by the shock, terrified by the explosion and force of its battery; but when we consider and examine it as the cause of thunder, lightning, aurora borealis, and other appearances of nature, whose direful effects we can in part imitate, explain, and even avert, we are then involved in a maze, that leaves nothing to contemplate but the inexpressible and permanent idea of admiration and wonder.

The earliest account we have of any known electrical effect, is by the famous ancient naturalist THEOPHRASTUS, who flourished about 300 years before the present era. He tells us that *amber* (whose Greek name is *ηλεκτρον*, and from whence the name *Electricity* is derived) as well as the *lyncurium**, has the property of attracting light bodies. This was all that was known of the subject, for about fif-

* It hath been in a manner proved, that the *lyncurium* of THEOPHRASTUS is the very same substance that now goes under the name of *Tourmalin*; of which we shall have occasion to speak in the course of this Treatise.

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teen centuries after THEOPHRASTUS; in which long period we find no mention in history of any person having made any discoveries, nor even any experiments in this branch of philosophy; the science remaining quite in the dark till the time of WM. GILBERT, an English physician, whose work *de magnete*, which contains several electrical experiments, was published in the year 1600; and who, for his discoveries in this new and uncultivated field, may be justly deemed the father of the present Electricity. He observed, that the property of attracting light bodies, after rubbing, was not peculiar to amber, or the *lyncurium*; but that many other bodies possessed it as well as amber. He mentions a great number of those, together with many particulars, which, considering the state of the science at that time, may be deemed truly great and interesting.

After GILBERT, the science advancing, although by small degrees, passed, as it were, from infancy to puerility; many an excellent philosopher undertaking to examine nature in this walk: such was Sir
FRANCIS

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FRANCIS BACON, Mr. BOYLE, OTTO GUERICKE, Sir ISAAC NEWTON, and most of all Mr. HAWKESBEE, a person to whom we are much indebted for many important discoveries, and a real advancement of Electricity. Mr. HAWKESBEE was the first who observed the great electric power of glass; a substance, that, since his time, has been generally used by all Electricians, in preference to any other electric. He first remarked various appearances of the electric light, and the noise accompanied with it, together with a variety of phenomena relating to electric attraction and repulsion.

After Mr. HAWKESBEE, the science of Electricity, however hitherto advanced, remained for about twenty years in a state of quiescence, the attention of philosophers being at that time engaged in other philosophical subjects, which, on account of the new discoveries of the incomparable Sir ISAAC NEWTON, were then greatly in repute. Mr. GREY was the first, after this period of oblivion, to bring the science again to light. He, by
7 his

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his great discoveries, re-introduced it to the acquaintance of philosophers, and from him the true flourishing era of Electricity may be said to take its date.

The number of Electricians that hath been daily multiplying since Mr. GREY, the discoveries made, and the use derived from those, till the present time, are matters really worthy of attention, and deserve to be admired by every lover of the sciences, and well-wisher to the human race.

Whoever would make himself acquainted with the particular transactions concerning those advances, should read the elaborate History of Electricity compiled by the learned Dr. PRIESTLEY, a work that will inform him of whatever had been done relative to the subject till its publication. I, for my part, must forbear making any long historical detail; this treatise being intended to give an account of the present state of Electricity, in a methodical manner, and not an history of the same. I shall in general only observe, that although the science

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science had, through the indefatigable attention of so many ingenious persons, and by the discoveries that were daily produced, excited the curiosity of philosophers, and engaged their attention ; yet, as the causes of any thing, whether small or great, known or unknown, are seldom much attended to, if their effects are not striking and singular ; so Electricity had, till the year 1746, been studied by none but Philosophers. Its attraction could in part be imitated by a loadstone ; its light by a phosphorus ; and, in short, nothing contributed to make Electricity the subject of the public attention, and excite a general curiosity, until the capital discovery of the vast accumulation of its power, in what is commonly called the *Leyden phial*, which was accidentally made in the memorable year 1745 *. Then, and not till then, the study of Electricity became general, surprised every beholder, and invited to the

* This great discovery was made by Mr. VON KLEIST, Dean of the Cathedral in Comin. See the third edition of Dr. PRIESTLEY's Hist. of Elect. Per. VIII. Sect. 1.

houses

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houses of Electricians a greater number of spectators, than were before assembled together to observe any philosophical experiments whatsoever.

Since the time of this discovery, the prodigious number of Electricians experiments, and new facts that have been daily produced from every corner of Europe, and other parts of the world, is almost incredible. Discoveries crouded upon discoveries; improvements upon improvements; and the science ever since that time went on with so rapid a course, and is now spreading so amazingly fast, that it seems as if the subject would be soon exhausted, and Electricians arrive at an end of their researches: but, however, the *ne plus ultra* is, in all probability, as yet at a great distance, and the young Electrician has a vast field before him, highly deserving his attention, and promising further discoveries, perhaps equally, or more important than those already made.

A Com-

COMPLETE TREATISE, &c.

PART I.

FUNDAMENTAL LAWS OF ELECTRICITY.

CHAP. I.

*Containing the Explanation of some Terms
principally used in Electricity.*

IF a person, holding with one of his hands a clean and dry glass tube, rubs it with his other hand, also clean and dry, stroking it alternately upwards and downwards; and after a few strokes, presents to it small light bits of paper, thread, metal, or any other substance, the rubbed tube will immediately attract them, and

B

after

after a little time will repel them—presently, attract them again; and so alternately continue this attraction, and repulsion, for a considerable time. If this tube be rubbed in the dark, and, after having been rubbed, a finger be presented to it at the distance of about half an inch, a lucid spark will be seen between the finger and the tube, accompanied with a snapping noise; the finger at the same time receiving a push, as if it was from air issuing with violence out of a small pipe.

In this experiment, the attraction, repulsion, sparkling, &c. are the effects of that unknown cause called *Electricity*; and hence they are called *electrical appearances*. The glass tube itself is called the *electric*, and all those bodies which are capable by any means to produce such effects, are called *electrics*; and as the rubbing awakes, as it were, in them the power of producing electrical appearances, they are therefore said to be *excited* by the rubbing. The hand, or any other body that rubs an electric, is called the *rubber*; and if, instead of the person rubbing the glass tube, a machine

a machine be constructed capable by any means to excite an electric, this will be an *electrical machine*.

If at the end of the tube opposite to that held by the hand, a wire of any length be tied, suspending a metallic ball at its end, and the tube be excited as before, the metallic ball will, in this case, acquire all the properties of the excited tube, *i. e.* it will attract, sparkle, &c. like the tube itself, the electric virtue passing through the wire to the ball: hence, the wire is said to be a *conductor* of electricity; and all such bodies as are capable to transmit the electric virtue, like the above-mentioned wire, are called *conductors*.

But if, instead of the wire, a silk string be used in the above experiment, and the tube be excited as before, the ball in this case will not shew any signs of Electricity; the silk string not permitting the electric virtue to pass from the tube to the ball: hence the silk string in this case, and all those substances through which the electric

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virtue cannot be transmitted, are called *non-conductors*.

A body resting intirely upon non-conductors is said to be *insulated*; so, in the last experiment, the metallic ball was insulated; since it was suspended intirely by the silk string, which is a non-conductor. The bodies which are conductors, and those which are non-conductors of electricity, together with their peculiar properties, as far as they are known, will be plainly laid down in the following chapters.

C H A P. II.

TH E first and principal maxim in Electricity is, that all the known bodies in nature are divided into two classes, viz. Electrics, and Conductors; experiments shewing, that whatever substance is a Conductor of Electricity, cannot be excited, (hence Conductors are also called *non-electrics*); and that whatever substance can be excited, is not a Conductor, (hence *Electrics* and *Non-conductors* become synonymous terms *.) This maxim, however, is not to be considered as strictly true and general; for in reality we know of no substance that may be called a perfect Electric, nor of any, that may be called a perfect Conductor; the Electric virtue finding some resistance in going through the best Conductors, and being in part transmitted through, or over the surface of most, and perhaps all the Electrics. The less perfect Conductor any substance is, the nearer

* Electrics are often also called *Electrics per se*.

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it comes to the nature of an Electric; and, on the other hand, the less perfect Electrics come nearest to the nature of Conductors. The limits of those two classes come so far one within the other, that there are many substances which may be actually excited, and at the same time are pretty good Conductors. If the reader desires to know those ambiguous substances, he must seek for the worst Electrics among the Electrics, and for the worst Conductors among the Conductors, excepting such on which the experiment cannot be tried, as fluids, powders, &c.

The two following lists contain, in general, all the Electrics and Conductors, disposed in the order of their perfection, beginning in each list with the most perfect of their class. In this order, however, the reader must not expect a great exactness; that being impracticable, when substances are set under general articles; and at the same time is of little, if indeed of any use whatever.

ELECTRICS.

ELECTRICS.

Glass, and all vitrifications, even those of metals.

All precious stones, of which the most transparent are generally the best.

All resins †, and resinous compounds.

Amber.

Sulphur.

Baked wood.

All bituminous substances.

Wax.

Silk.

Cotton.

All dry animal substances, as feathers, wool, hair, &c.

Paper.

White sugar, and sugar-candy.

Air.

† Under the name of resins, I would be understood to mean all such consistent, oily, vegetable, productions as are inflammable, and not soluble in water; gum-lac, therefore, and all such substances, improperly called gums, are also meant under this article. See MACQUER's Chemistry, vol. i. chap. II.

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Oils ‡.

Calces of metals and semi-metals.

The ashes of animal and vegetable substances.

All dry vegetable substances.

All hard stones, of which the hardest are the best.

Many of the above-mentioned substances, and perhaps all those upon which the experiment can be made, when very hot, lose their electric property, and become quite, though not equally good, Conductors; so red-hot glass, melted resin, hot air, baked wood made very hot, &c. become Conductors of electricity. But it is very remarkable, that the focus of a burning-glass is not a Conductor of electricity. It has been observed, that glass, especially the hardest and best vitrified, is often a very bad Electric, sometimes being quite a Conductor. The Abbé Nollet and others have made various experiments relative to this property of glass, but without deter-

‡ Mr. CIGNA observed electrical attraction and repulsion between conducting substances plunged in oil. NOLLET'S Letters, vol. iii. p. 168.

mining intirely the causes which occasion the difference. Glass vessels, made for electrical purposes, are often rendered very good Electrics by use and time, though they might be very bad ones when new. On the other hand, some glass vessels, which had been long used for excitation, have sometimes lost their power almost intirely. I have twice observed indisputable cases of this sort.

A glass vessel, out of which the air has been exhausted, on being rubbed, shews no signs of electricity upon its external surface, but all the electric power appears within the vessel *; and a glass tube, or globe, with the air condensed in it, or full of some conducting substance, is incapable of being excited. But a solid stick of glass, of sealing-wax, &c. may be excited.

* Although a glass vessel, exhausted of air, does not shew any signs of electricity without; yet it has been observed, that the electric power of a glass cylinder is the strongest, when the air within it is a little rarefied, viz. somewhat less dense than the external air. See l' Eletticismo Artificiale of G. B. BECCARIA, § 411.

CONDUCTORS.

CONDUCTORS.

Gold.

Silver.

Copper.

Brass.

Iron.

Tin.

Quicksilver.

Lead.

Semi-metals.

Ores; of which the best are those that contain the metallic part in the greatest quantity, and come nearest to a metalline state.

Charcoals, made either of animal or of vegetable substances.

The fluids of an animal body.

All fluids, excepting air and oils*.

The effluvia of flaming bodies.

Ice†.

Snow.

* Salt water is a better Conductor than fresh water.

† Mr. ACHARD, being at Berlin, in the month of January 1776, observed, that water froze to the twentieth degree below 0 of Reaumur's thermometer (which

Snow.

Most saline substances, of which the metallic salts are the best.

Stony substances, of which the hardest are the worst.

Smoke.

The vapours of hot water.

Electricity pervades also vacuum, or the absence of air caused by an air-pump, al-

(which answers to the thirteenth degree below 0 of Fahrenheit's scale) was an electric. He tried his experiments in the open air, where he found that a rod of ice two feet long, and two inches thick, was a very imperfect Conductor, when Reaumur's thermometer was at six degrees below 0, and that it would not in the least conduct, when the thermometer was at 20°. By whirling a spheroid of ice in a proper machine, he even electrified the prime conductor, so as to attract, repel, give sparks, &c. The ice that this gentleman made use of, was free from bubbles of air, and quite transparent; to produce which, he used to set a vessel, containing distilled water, to be frozen, upon the window of a room, which was rather warm with respect to the ambient air; where the water began to freeze on one side of the vessel, while on the other side it was still liquid; in which case, he says that the bubbles of air, separated from the part of the water that began to freeze first, and passed gradually into the liquid part, so as to leave a considerable thickness of ice quite transparent.

most as freely as the substance of a good Conductor*.

Besides these, all bodies, in which more or less of some of the above-mentioned Conductors are contained, are also proportionably Conductors; thus, green vegetables, raw meat, &c. are Conductors, on account of the fluids they contain.

From this principle it follows, that all Electrics, before excitation, should be well cleaned, dried, and some made even very hot, in order to free them from every humidity; otherwise they are so far from the nature of Electrics, that they become actually Conductors, on account of the

* “I beg leave to mention in this place, as favourable to this hypothesis, a most curious discovery made very lately by Mr. WALSH; who, being assisted by Mr. de LUC to make a more perfect vacuum in the double or arched barometer, by boiling the quicksilver in the tube, found that the electric spark or shock would no more pass through it, than through a stick of solid glass.”—
Dr. PRIESTLEY’s Exp. and Obs. on different Kinds of Air, vol. i. p. 284.

moisture

moisture which they contain within their pores, or upon their surfaces.

In regard to the conducting power of charcoal, it must be observed, that all charcoal will not conduct equally well, there being some that will hardly conduct at all; and sometimes is in such a state, that it will assist the passage of a large quantity of electric fluid along its surface, when it will not conduct it any other way. This difference, however, is not occasioned by the difference of the wood from which the coals are made, but by the degree of heat that is applied in the process of making them; the best Conductors being such as have been exposed to the greatest heat *.

Whether the piece of wood in the process of coaling is suffered to flame, or not, is quite immaterial; and the continuance of the same degree of heat has no apparent effect with respect to the conducting power of the charcoal.

* See Dr. PRIESTLEY's second volume of Observations on different Kinds of Air, Sec. xiv.

It will not be improper to observe in this place, the different changes from Conductor to Non-conductor, occasioned in the same substance by different preparations. A piece of wood just cut from a tree is a good Conductor; let it be baked, and it becomes an Electric; burn it to a coal, and it is a good Conductor again; lastly, let this coal be reduced to ashes, and these will be impervious to electricity. Such changes are also observable in many other bodies; and very likely in all substances there is a gradation from the best Conductors to the best Non-conductors of Electricity.

C H A P. III.

Of the two Electricities.

IF, in the experiment mentioned in the first chapter, the person that rubs the tube be insulated, *i. e.* be set with his feet upon a cake of resin, a stool with glass feet, or any other good Electric, so that the communication between his body and the earth be cut off by means of Electrics; and if in this situation he rubs the tube with his hand, as before; this person, as well as the tube, will, in this case, appear electrified. If any light bodies be presented to any part of his body, they will be attracted and repelled. If another person presents his finger to him, a lucid spark will follow, with a snapping noise; and, in short, this insulated person will shew every sign of electricity that the tube exhibits. But their electricities are not the same; the electricity of the tube being just the reverse of the electricity of the person: and their particular appearances are the following:

1. Whenever

1. Whenever a light body insulated, as, for instance, a small piece of cork suspended by a silk thread, has been attracted by the tube, and afterwards repelled, if no conducting substance touches it in this state of repulsion, it will not be attracted by the tube again. The same happens with the insulated person; for when this light body has been once attracted by any part of his body, and afterwards repelled, it will not be attracted again; but if in this state of repulsion the tube be presented to it, then it will be attracted, and that violently, by the tube; and when repelled by the tube, it will be attracted by the insulated person. Further, if two or more light insulated bodies, like the above-mentioned piece of cork, be severally attracted by the tube, and when afterwards repelled, be brought within a small distance of one another, they will repel each other, and, if well insulated, continue in this electrified and repulsive state for a considerable time. The same will happen, if they are presented to the person instead of the tube; they will also, after being once repelled by this, repel one another. But,

if one, or more of those light insulated bodies be attracted and repelled by the tube; and one or more others be attracted and repelled by the person, and afterwards both or all (*i. e.* such as were presented to the tube, and such as were presented to the insulated person) be brought within a sufficient distance of one another, they will then, instead of repelling, attract each other; and instead of continuing electrified, extinguish at once every sign of electricity. These two electricities, therefore, are (as was said before) the one just the contrary of the other, the one attracting what the other repels; and, as if one was an affirmative, and the other a negative power, when equal quantities of each are summed together, they balance each other, and lose every property.

2. Another characteristic of each of the two electricities, consists in the appearance of their light. If a pointed body, as a needle, a wire, or the like, be presented to the excited tube in the dark, a lucid globule, like a star, will be seen upon the point; but if this pointed body be presented to the insulated person, then in the

C

place

place of the star a lucid pencil appears, composed of rays, seemingly issuing from the point, and diverging towards the person †.

3. Lastly, in some experiments (which will be hereafter particularly mentioned, and this property better explained) the electricity of the tube, when in the act of passing from a body overcharged with it to another, either not electrified, or possessed of the contrary electricity, shews an indisputable current from the former to the latter; and the electricity of the insulated person, when in the act of passing from a body overcharged with it to another, either not electrified, or possessed of the contrary electricity, shews clearly a current from the latter to the former.

These two electricities are not only observed in the above-mentioned experiment, but in several other cases also; and they always accompany each other; for when

† This pencil of rays will appear better, if a pointed needle be presented to the insulated person, at the distance of about one inch from some part of his body, while he is actually rubbing the tube in the dark.

different

different Electrics are rubbed, some will acquire one electricity, and others will acquire the contrary; the rubber, if insulated, shewing at the same time, signs of the electricity contrary to that acquired by the excited electric: besides this, almost all Electrics may be made to shew at pleasure the one or the other electricity, according to the substance used for a rubber. Hence the following corollaries may be deduced: *viz.* 1. Whenever two different substances (being both insulated, or only that which is a Conductor) are rubbed together, except they are both good Conductors, they will be both electrified, and one acquire the electricity contrary to the electricity of the other. 2. Almost all the Electrics may be made to acquire, at pleasure, the one or the other electricity, by using proper rubbers.

The first of these two electricities, *i. e.* that possessed by the glass tube in the above experiment, as it was thought to be the constant production of rubbed glass, was called the *Vitreous Electricity*; and the other, as it was first observed to be produced by resinous substances, was called

the *Resinous Electricity*. The Vitreous Electricity is also called *Positive* or *Plus Electricity*, for a reason that will be considered in the course of this Treatise; and the Resinous is called also *Negative* or *Minus Electricity*. A body, therefore, possessed of the Vitreous, Positive, or Plus Electricity, is that which shews such signs as the tube was said to exhibit; and a body possessed of the Resinous, Negative, or Minus Electricity, is that which shews such signs as the insulated person was said to exhibit in the above-mentioned experiment.

In the following Table may be seen what Electricity will be excited in different bodies, when rubbed with different substances. Smooth glass, for instance, will be found by this Table to acquire a Positive Electricity, when rubbed with any substance hitherto tried, except the back of a cat, (by which I mean the skin of a cat while on the animal alive); rough glass, *viz.* glass the polish of which has been destroyed by emery or otherwise, will be found to acquire the Positive Electricity, when rubbed with dry oiled silk, sulphur, &c. and the Negative, when

when rubbed with woollen cloth, the hand, &c. and so of the rest.

The back of a cat	Positive	{ Every substance with which it has been hitherto tried.
Smooth glass	Positive	{ Every substance hitherto tried, except the back of a cat.
Rough glass	Positive	{ Dry oiled silk, sulphur, metals.
	Negative	{ Woollen cloth, quills, wood, paper, sealing-wax, white-wax, the human hand.
Tourmalin	Positive	{ Amber, air*.
	Negative	{ Diamond, the human hand.
Hare's skin	Positive	{ Metals, silk, loadstone, leather, hand, paper, baked wood.
	Negative	{ Other finer furs.
White silk	Positive	{ Black silk, metals, black cloth.
	Negative	{ Paper, hand, hairs, weasel's skin.
Black silk	Positive	{ Sealing-wax.
	Negative	{ Hare's, weasel's, and ferret's skin, loadstone, brass, silver, iron, hand.
Sealing-wax	Positive	{ Metals.
	Negative	{ Hare's, weasel's, and ferret's skin, hand, leather, woollen cloth, paper.
Baked wood	Positive	{ Silk
	Negative	{ Flannel.

* i. e. By blowing with a pair of bellows upon it. By this means many Electrics may be excited, and some better if the air blown is hot, although, in both cases, very little Electricity can be obtained.

The preceding Table might have been much extended, had I chosen to bring into it all the minutiae attending this matter as far as is known; but this I have thought unnecessary and impracticable, because experiments of this kind are of so nice a nature, that they require the most scrupulous attention in making them; and then their effects depend upon so small and variable circumstances, that often the very same Electric, rubbed with the same rubber, gives at one time signs of one Electricity, and at another time signs of the contrary. A very little alteration in the surface, a different degree of dryness, and even a different application of the same substances, often occasions a difference in the Electricity. I shall only observe in general, that as far as may be deduced from the greatest number of experiments, it appears, that when different substances are rubbed together, that whose Electric power is the strongest, in general acquires the Positive, and the other the Negative Electricity; and when two bodies, differing in the smoothness or roughness of their surfaces, are rubbed together, the smoothest acquires the Positive, and the

the roughest the Negative Electricity. These two qualities are often to be considered both together; for, except the two bodies are of the same substance, as smooth and rough glass, white and black silk, &c. they generally differ in both, viz. they have not the same electric power, and at the same time their surfaces differ in smoothness. This rule, however, is not to be considered as a constant and general one; for, according to this principle, it should seem, that a piece of sealing-wax, when rubbed with the hand, or paper, would acquire the Positive Electricity; but this is contrary to experience.

In case that two electric substances, equal in every respect, are rubbed together, it is to be observed that the substance which suffers the greatest friction acquires the Negative, and the other the Positive Electricity. Suppose, for instance, that a piece A of silk be drawn across another piece of silk B, in every respect equal to the former, so that the surface of the whole piece A, *i. e.* of one side of it, be successively drawn over one part of the piece B, then A will acquire the Positive, and B the Negative Electricity. The

reason of this may probably be, because the part of the piece B, over which the piece A has been drawn, has acquired a greater degree of heat; for it has been observed, that heat rather disposes bodies to be electrified Negatively.

C H A P. IV.

Of the different Methods of exciting Electrics.

RUBBING, as we observed before, is the general mean by which all electric substances that are at all excitable, may be excited. Whether they be rubbed with Electrics of a different sort, or Conductors, they always shew signs of Electricity, and in general stronger when rubbed with Conductors, and weaker when rubbed with Electrics. But besides friction, there are other means by which some Electrics may be caused to shew electric appearances: these are, by melting, or pouring a melted Electric into another substance; and by heating or cooling. The particulars observed by using the first of these two methods are the following:

If

If sulphur be melted in an earthen vessel, and left to cool upon Conductors : if taken out of the vessel, when cold, it will be found strongly electrical ; but not at all so, if it be left to cool upon Electrics.

If sulphur be melted in glass vessels, and afterwards left to cool, they will both acquire a strong Electricity, the sulphur Negative, and the glass Positive, whether they be left to cool upon Electrics or Conductors ; however, they always acquire a stronger power in the former case than in the latter, and a stronger still, if the glass vessel is coated with metal. It is remarkable that the sulphur acquires no electricity till it begins to cool ; its power increases in proportion as it contracts, and is the strongest when in the state of greatest contraction ; but then the electricity of the glass vessel is at the same time the weakest.

If melted sulphur be poured into a vessel of baked wood, it acquires a Negative, and the wood a Positive Electricity ; but if it be poured into sulphur, or rough glass, it acquires no sensible electricity.

Melt

Melted sulphur poured into a metal cup, and there left to cool, shews no signs of Electricity whilst in the cup ; but if they are separated, they will then appear strongly electrified, the sulphur Plus, and the cup Minus. If the sulphur is again replaced in the cup, every sign of Electricity will vanish ; but if, whilst they are separate, the Electricity of either of them is taken off, they will both, on being replaced, appear possessed of that Electricity which has not been taken off.

Melted wax, poured into glass, or wood, acquires a Negative Electricity, and leaves the glass or wood Positive. But sealing-wax poured into sulphur, acquires a Positive Electricity, and leaves the sulphur Negative.

Chocolate, fresh from the mill, as it cools in the tin pans in which it is received, becomes strongly electrical : when turned out of the pans, it retains for some time this property, but soon loses it by handling. Melting it again in an iron ladle, and pouring it into the tin pans as at first, will for once, or twice, renew the power ; but,
when

when the mass becomes very dry, and powdery in the ladle, the Electricity is revived no more by simple melting; but if then a little olive oil be added, and mixed well with the chocolate in the ladle, on pouring it into the tin pan, as at first, it will be found to have completely recovered its electric power †.

Now that we are speaking of melted Electrics, it will not be improper to observe, that it sometimes happens, that some electric substances, by being melted and left to cool, acquire an electrical power, which they retain for a considerable time, often for months together, especially if they are preserved free from dampness and dust. Such effects have sometimes induced Electricians to think, that some bodies are possessed of a permanent or perpetual Electricity, which is as inherent in their substance as the magnetic power of a loadstone: in truth, however, no such substance has yet

† The above remark on chocolate, together with the method of restoring its power by means of olive oil, is a recent discovery of the late Mr. W. HENLY, F. R. S.

been

been found ; and although rosin, sulphur, amber, and some other Electrics, shew signs of Electricity for a considerable time after they have been rendered electrical, yet their power is continually diminishing till it quite vanishes. It is remarkable, however, that sulphur, resinous, and bituminous substances, retain in general the electric power much longer than glass, or any other Electrics ; the reason may be, that they do not attract moisture like glass and other substances.

If a stick of sealing-wax be broken into two pieces, the extremities that were contiguous will be found electrified, one positively, and the other negatively.

The property of exhibiting electrical phenomena, by means of heating and cooling, was first observed in a hard semi-pellucid fossil, known under the name of Tourmalin †. This stone, which is generally of a

† This stone is called *aschentricker* by the Dutch, from its property of attracting the ashes, when laid near the fire. Linnæus calls it *lapis electricus*. See his *Flora Zeylonica*.

deep red, or purple colour, and seldom exceeds the size of a small walnut, is common in several parts of the East Indies, and especially in the island of Ceylon. Its properties in regard to Electricity are the following:

1. The Tourmalin, while kept in the same degree of heat, shews no signs of Electricity, but it will become electrical by increasing or diminishing its heat, and stronger in the latter than in the former circumstance. An exceedingly small variation of temperature is often sufficient to render the Tourmalin sensibly electrical.

2. Its Electricity does not appear all over its surface, but only on two opposite sides, which may be called its poles, and they always lay in one right line with the center of the stone, and in the direction of its strata; in which direction the stone is absolutely opaque: though on the other, semi-transparent.

3. Whilst the Tourmalin is heating, one of its sides (distinguished by A) is electri-

fied plus, and the other side B minus. But when it is cooling, A is minus, and B is plus *.

4. If it be heated, and suffered to cool without either of its sides being touched, then A will appear positive, and B negative, all the time of its heating or cooling.

5. If this stone be excited by friction, like any other Electric, then each of its sides, or both at once, may be made Positive.

6. If the Tourmalin be heated or cooled upon some other insulated body, that body will be found electrified as well as the stone, and possessed of the Electricity contrary to that, acquired by that side of the stone which was laid upon it.

* From this law may be easily deduced, that if one side of the stone, in some circumstance or other, is growing hot, while the other is cooling, then both sides will appear possessed of the same electricity at the same time; and if only one side changes its degree of heat, while the other remains the same, then the former side only will appear electrified.

7. The

7. The Electricity of each side, or of both, may be reversed by heating or cooling the Tourmalin in contact with various substances; so if it is cooled, or heated in contact with the palm of the hand, that side of it, which would have been positive if cooled in the open air, is now negative; and that, which would have been negative, is now positive.

8. If a Tourmalin be cut into several parts, each piece will have its positive and negative poles, corresponding to the positive and negative sides of the stone from which it was cut.

9. These properties of the Tourmalin are also observable in vacuo, but not so strong as in the open air.

10. If this stone be covered all over with some electric substance, as sealing-wax, oil, &c. it will in general show the same appearances with this coating, as without it.

11. Mr. WILLIAM CANTON hath lately observed a very vivid light to appear upon
5 the

the Tourmalin, while heating in the dark : he can by this determine, which end of the stone will be positive, and which negative. Further, when the stone is strongly excited, it emits very strong flashes from the positive to the negative end, in the dark †.

12. In the last place, it is remarkable that the power of the Tourmalin is sometimes injured by the action of a strong fire, sometimes improved, and sometimes not at all affected by it. The laws, however, of these uncertain effects have not yet been ascertained.

The most of the above properties, which were first observed, and thought peculiar to the Tourmalin, have been found to belong to several hard precious stones, they being also made electrical by heating and cooling, and have their positive and negative sides laying in the direction of their strata or crystals ; and, in short, as far as

† The Brazilian emerald, Mr. Canton has observed to have also this property of emitting light, whilst heating in the dark.

has

has been observed; they have been found to act exactly like Tourmalins.

We shall lastly observe, in this chapter of excitation, that whenever an Electric is rubbed with another insulated substance, although it acquires an electric power, and shews electrical appearances, yet that power is very weak; and in order to obtain a considerable Electricity, it is necessary that the rubber should have a regular communication with the earth, by means of good Conductors.

C H A P. V.

Of Communicated Electricity.

IN the preceding Chapters we have considered Electricity no further than in respect to its quality; we have remarked the differences between the Positive and the Negative, and have noted which bodies, and by what means, they could acquire this property.---But now a vast prospect is opening to our view, full of extraordinary appearances;

ances ; and we are to consider in this Chapter, not the mere kind of Electricity, but its numerous effects. Under the title of Communicated Electricity, falls almost all that is known of the subject; the passage of this virtue from one body to another is what causes its light ; by being communicated to other bodies, we see its attraction ; by its quick transition it is that it melts metals, destroys animal and vegetable life ; and, in short, it is by this communication that the science is at all known and cultivated. In order, therefore, to preserve perspicuity, and distinction in describing such a multitude of facts, I shall employ more chapters on this subject, and arrange in each such particulars as seem most proper to be placed together, at the same time contriving to reduce the whole into as few principal heads as is possible, without confusion.

Whenever Electricity is by any means superinduced on a body, it is there confined only by Electrics, and remains with that body a longer or a shorter time, according as the Electrics that confine it are
more

more or less perfect. A glass tube, for instance, when rubbed, acquires a quantity of that power, whatever it is, which we call Electricity. That Electricity remains, and is perceivable upon the glass, insomuch as it is surrounded by the air, which is an Electric; and as the air is in a more or less perfect electric state, so that virtue is retained upon the glass longer or shorter*; and because the air is never a perfect Electric, therefore the excited tube can never preserve the acquired Electricity perpetually, but is continually imparting some of it to the contiguous air, or the conducting particles that float in that element, 'till at last it quite loses its power. If a finger, or any other Conductor, be presented towards an excited Electric, it will receive a spark, and in that spark part only of the Electricity of the Electric; but why not all? Because the excited Electric, being a Non-conductor, cannot convey the Electricity of all its surface

* An excited glass tube, if kept in a dry and rather warm place, for instance, at some distance from a good fire, will continue electrified above twenty hours.

to that side, to which the Conductor has been presented. Hence, if a conducting substance be successively presented to different parts of an excited Electric, it will receive at every approach a spark, without repeating the excitation, 'till all the power of that Electric is exhausted, and then a new excitation is necessary in order to revive it.

Whenever a Conductor communicating with the earth is exhibited at a convenient distance to an excited Electric, it acquires on that exhibited side an Electricity contrary to that possessed by the Electric: this Electricity increases the nearer it is approached, and at last, as there is an eager attraction between Positive and Negative Electricity, the Conductor receives a spark from the Electric, and so the balance is restored. If this Conductor does not communicate with the earth, but is insulated, and approached to the excited Electric as before, then not only that side of it which is towards the Electric, but the opposite also, will appear electrified; with this difference, however, that the side, which is exposed
to

to the influence of the Electric, has acquired an Electricity contrary to that of the excited Electric, and the opposite side an Electricity of the same kind with that of the Electric. These two different Electricities of the Conductor increase as it comes nearer to the Electric, and at last, the former receiving a spark from the latter, becomes throughout possessed of the same Electricity with the Electric from which it has received the spark. All these effects will happen in the same manner, if between the excited Electric and the approached Conductor there is interposed some other electric substance besides air; as for instance, a thin plate of glass, rosin, sealing-wax, &c. but then a spark can never come from the excited Electric to the Conductor, except it forces, or bursts its way through the interposed Electric, as it always does through the air. This displacing of the air is what causes the noise that attends a spark, and that noise is more or less loud in proportion to the quantity of Electricity, and to the resistance it meets with in its passage.

An insulated Conductor having received the Electricity from an excited Electric, (in which state it is said to be electrified by communication) will act in every respect like the excited Electric itself, except, that when it is touched by another Conductor communicating with the earth, the former gives one spark to the latter, and by that discharges all its Electricity. The reason why an electrified Conductor loseth its Electricity all at once, when touched with another Conductor communicating with the earth, and not part of it only, like the excited Electric, is, because the Electricity belonging to the whole of the Conductor is easily conducted through its own substance, to that side, to which the other Conductor is presented. Hence it appears that, in general, the Electricity discharged from an electrified Conductor is much more powerful, than when discharged from an Electric; for the Conductor may acquire a great quantity of Electricity from an Electric, by receiving spark after spark, and afterwards if touched, will discharge it all at once, and not by little and little as it was received.

If

If an insulated Conductor be touched with another Conductor electrified, it will acquire part of the Electricity belonging to the electrified Conductor, and afterwards each will show signs of it. The Electricity in this case will not always be equally divided between the two Conductors, nor will it keep any proportion to the quantity of matter in each contained; but will observe the following laws.

1. If two insulated Conductors, that in respect to their external surfaces are equal and similar, and both, or only one electrified, are touched together, the Electricity will be equally divided among them.

2. If their surfaces are equal and dissimilar, as for instance a square foot of tin foil in one piece, and another square foot of it cut in a long slip, then that body, whose surface has a greater extension, will acquire more Electricity than the other.

3. Lastly, if their surfaces are unequal and dissimilar, the Electricity that each acquires after the contact, seems pretty clear from experiments, and in consequence of

the above two laws, to be in a compound proportion of their surfaces, and the extensions of the same.

The electric spark (*i. e.* a separate quantity of Electricity) will go a greater or less distance through the air, in order to reach a Conductor, according as its quantity is greater or less; as the parts from which it flies off, and on which it strikes, are more sharp or more blunt, and as the Conductor is more or less perfect. The noise together, and the light with which the spark is attended, is greater or less, according as the Electricity is greater or less; as the parts from which it flies, and on which it strikes, are more blunt or more sharp; and as the Conductor is more or less perfect. Thus, for instance, a sharp-pointed body will throw off Electricity to, and receive it from a greater distance, than a body of any other shape; but then that passage occasions no noise, and but little light; for, in this case, the Electricity does not come in a separate large body, but by little and little, or rather by a continued stream. If a pointed wire is concealed in a glass tube, which projects a short way beyond it, or
if

if it is covered with tallow, bees-wax, sulphur, &c. then it will take a strong spark from an electrified Conductor.

It is remarkable in the case of points throwing off, or receiving Electricity, that a current of air is sensible at an electrified point, which is always in the direction of the point, whether the Electricity is positive or negative.

The electric spark, taken upon any part of a living animal body, causeth a disagreeable sensation, which is more or less troublesome, as the spark is stronger or weaker, and the part, upon which it is taken, is more or less delicate; and also according to the particular constitution of individuals.

A pretty large quantity of Electricity pervades the substance of a Conductor of a considerable length, with a surprising and imperceptible velocity; but a small quantity of it has been found to take some little time in passing through a long, and less perfect Conductor.

Bodies,

Bodies, possessed of the same Electricity, whether positive or negative, repel each other. But bodies, possessed of different Electricities, attract each other; and there is no electric repulsion, but between bodies possessed of the same Electricity, nor electric attraction, but between bodies possessed of different Electricities, *i. e.* between bodies positively, and bodies negatively, electrified‡.

Electricity, strongly communicated to insulated animal bodies, quickens their pulse, and promotes their perspiration. If it is communicated to insulated fruits, fluids, and in general, to every kind of bodies that are actually in a state of evaporation, it also increaseth that evaporation, and that in a greater or less degree, as those bodies are

‡ This law, *i. e.* that there is no electric attraction, except between bodies possessed of different Electricities, will, perhaps, appear paradoxical, upon observing, that an excited Electric attracts small bodies, which never were by any means made electrical before; but the paradox will soon vanish, if what has been said above be considered, *i. e.* that when Conductors, and indeed Electrics too, come near an electrified body, they become actually possessed of a different Electricity, But this will appear much clearer from the experiments that are to be mentioned hereafter.

more or less subject to evaporate of themselves, as the vessels, that contain the same, are Conductors or Electrics, and as they have a greater or less surface exposed to the open air §.

By encreasing the perspiration of vegetables, Electricity promotes their growth; it having been found, after several accurate experiments, that such plants, which have been often, and long electrified, have shewed a more lively and forward appearance, than others of the same kind that were not electrified*.

When Electricity is communicated to insulated vessels, containing water, that is ac-

§ Although it has been by some pretended, that Electricity caused several substances to evaporate through the pores of glass, and metals, yet that could never be observed, though many accurate experiments were made for that purpose; besides, this pretended evaporation, seems on all accounts exceedingly improbable.

* It is said by Mr. KOESTLIN to have been found, that negative electrization retards both animal and vegetable life.—See his Latin Dissertation on the effects of Electricity upon some organic bodies.

tually

tually running from a pipe, the effects will, as far as may in gross be deduced from experiments, observe the following laws.

“ 1. The electrified stream, though it divides, and carries the liquid further, is neither sensibly accelerated nor retarded, when the pipe through which it issues is not less than a line in diameter.

“ 2. Under this diameter, if the tube is wide enough to let the liquid run in a continued stream, Electricity accelerates it a little, but less than a person would imagine, if he judged by the numbers of jets which are formed, and by the distance to which they go.

“ 3. If the tube be a capillary one, from which the water only drops naturally, the electrified jet not only becomes a continued stream, and even divided into several streams, but is also considerably accelerated; and the smaller the capillary tube is, the greater, in proportion, is the acceleration.

“ 4. So

“ 4. So great is the effect of the electric
“ virtue, that it drives the water in a con-
“ stant stream out of a very small capillary
“ tube, out of which it had not before been
“ able even to drop.”

The electric power has been found not to be affected by, or affect, the magnetic virtue of a loadstone; neither is it affected by heat or cold; since, an iron bar made red-hot, or any conducting substance hard frozen, when electrified, attracts, repels, gives sparks, &c. nearly in the same manner as in its natural temperature. Electric attraction is observable also in vacuo, where it acts nearly at the same distance as in the open air; and electric substances may also be excited in vacuo.

Lastly, we shall conclude this chapter with remarking, that if the face or any part of the body, is presented to an excited Electric, or to a Conductor strongly electrified, it will feel as if a wind was blowing, or rather, as if a spider's web was drawn over it: also, if the nostrils are presented to an excited Electric, they will be affected by a smell, much resembling
that

that of phosphorus; but communicated Electricity does not occasion any such sensation, except when a large quantity of it does suddenly pass from one body to another. If bodies are kept for some time within the electric effluvia when strong, they will retain the smell that they acquire, for a considerable time after.

C H A P. VI.

Of Electricity communicated to Electrics.

AS the Electric Virtue can be superinduced on Conductors by communication, so may it also be communicated to Electrics: the difference however is, as might be expected, very remarkable; for when one side of a Conductor is presented to an electrified body, the Electricity will instantly pervade its whole substance, on account of its conducting nature; whereas, when an Electric is presented to another Electric excited, or to an electrified Conductor, it will with some difficulty acquire
any

any Electricity, because its substance is impervious to that virtue ; and in order to make it acquire some, it must be several times, and in different parts, touched with the electrified body. That it is as difficult to deprive an Electric of its acquired Electricity, as it is to superinduce it on its surface, I think might easily be supposed ; for the very same quality, which causeth it to acquire that power slowly (namely its being a Non-conductor) makes it also part with it slowly ; and, in order absolutely to deprive the Electric of its acquired Electricity, it must be touched several times, and in almost every part of its surface, with some conducting substance.

In the preceding chapter we observed, that when an insulated Conductor is presented to an electrified body, it acquires, on the part nearest to that body, a contrary Electricity ; and on the opposite part, an Electricity of the same kind with that of the electrified body ; we also observed, that these two Electricities increase, as the Conductor comes near to the electrified body, and that when the Conductor is arrived

rived within the striking distance of that body, a quantity of Electricity flies off from the latter; forces its way through the intermediate air, and, striking upon the former, renders it throughout possessed of the same Electricity. These effects are in a certain degree also observable when an Electric, instead of a Conductor, is presented to an electrified body; for the Electric will also acquire, on different sides, contrary Electricities: these Electricities increase, as the distance decreases; but, if at last a small quantity of Electricity is communicated to one part of the Electric, that Electric will not become throughout possessed of one Electricity, but will still, in some cases, shew different Electricities on different sides; and in some circumstances, many repeated changes from positive to negative Electricity may be observed upon the same Electric, as will appear from the following experiment.

If the end of a pretty long glass tube be presented to a body electrified, for instance positively, the tube will be found electrified positively also for the space of one or
two

two inches at the end; but, beyond that space, will be found two or three inches electrified negatively; after that, another positive Electricity will appear, and so alternately, a positive and a negative zone will follow one another, always weaker and weaker in power, till at last they quite vanish *. Now the cause of these effects is always to be deduced from the two above-mentioned principles, *i. e.* the non-conducting quality of an Electric, and the properties of bodies in general to acquire an Electricity contrary to that possessed by another contiguous electrified body: so in the above experiment, that end of the tube which was presented to the body electrified positively, before it received any Electricity from that body, appeared negative on the part presented to it, but after it had received some Electricity, appeared to be positive no further than that Electricity could be spread over its surface; but beyond that place a part of the tube appeared to be negative, on account of its

* See PRIESTLEY'S Hist. of Elect. Per. X. Sect. v. or *Æpini Tentamen*, p. 192.

contiguity to the part electrified positively; after that, another place appeared to be positive, because of its contiguity to the part electrified negatively, and so of the subsequent changes; and the positive Electricity of one part of the tube cannot mix with the adjoining negative part, so as to prevent these appearances, because the non-conducting quality of the glass will always hinder such an effect from taking place.

If to one side of an Electric sufficiently thin, as for instance a pane of common window-glass, a plate of sealing-wax, &c. be communicated one Electricity, and to the opposite side be communicated the contrary, that plate in that case is said to be *charged*, and the two Electricities can never come together, except a communication of conducting substances be made between both sides, or the Electric be broken by the power of electric attraction. When the two Electricities of a charged Electric are by any means united, and therefore their power destroyed, that Electric is then said to be *discharged*, and the act of union
of

of these two opposite powers is, for a reason hereafter to be mentioned, called the *electric Shock*.

In order to avoid the difficulty of communicating Electricity to an electric plate, it is customary to coat the sides of it with some conducting substance, as tin-foil, gilt paper, &c. by which means the charging and discharging becomes very easy; for when the Electricity is communicated to one part of the coating, it is immediately spread through all the parts of the Electric that are in contact with that coating, and when the Electric is to be discharged, it is sufficient to make a conducting communication between the coatings of both sides, in order to discharge entirely the Electricities of that Electric.

It will be readily understood why the coatings of both sides of an Electric should not come very near one another towards the edge of the plate, for then a communication between the same coatings is ready at hand, and although they do not absolutely touch one another, yet when they are elec-

trified, the Electricity will easily force a passage through the air, and, by passing over the surface of the Electric from one coating to the other, renders it incapable of receiving any charge*.

By means of charged Electrics, we may see a display of the greatest powers of Electricity; we can accumulate this power, and use it advantageously in different experiments. By considering the properties of a charged Electric, we become further and better acquainted with this science, than by any other means; and for the enumeration of these properties the following chapter is employed.

* The property of conducting the Electricity over the surface is so remarkable in some kinds of glass, that they are on this account absolutely unfit for the purpose of charging and discharging.

C H A P. VII.

Of charged Electrics, or the Leyden Phial.

IF a glass plate, whether smooth, or rough, is coated with some conducting substance on both sides, so that the coatings do not come so very near the edge of the glass, as to render it unfit to be charged, and if to one of those coatings be communicated some Electricity, the other coating, while communicating with the earth, or with a sufficient quantity of conducting bodies, acquires by itself an equal quantity of the contrary Electricity; but if, whilst one side is acquiring Electricity, the opposite side does not communicate with the earth, or with a sufficient quantity of conducting substances, the glass cannot be charged*. Now the reason why, when one side of the glass is receiving one Electricity, the opposite side acquires the other, is the

* Strictly speaking, the glass in this case will be charged a little, because the air which is contiguous to its coating is not a perfect Non-conductor.

same as observed in the preceding chapter, *i. e.* the property of bodies to acquire an Electricity contrary to that possessed by a contiguous electrified body; and the cause, that hinders these two Electricities from mixing together, is the interposition of the glass plate, which is impermeable to Electricity; but if the charge is too high, and the glass plate too thin, then the great attraction, between the two different Electrics, forces a passage through the glass, discharges it, and renders it unfit to receive another charge*.

These effects happen in the same manner if the glass be not in the form of a plate, but in any other shape whatsoever, provided it is sufficiently thin, it being not the

* This remarkable property of Electricity was first satisfactorily observed (though not originally discovered, as we have already taken notice in the Introduction) at Leyden with a bottle containing some water, which served for the inside coating, and the undesigned application of the hands on the outside served for another coating. A bottle coated on the inside and outside for the purpose of being charged, has from thence been called the *Leyden Phial*, otherwise an *electric Jar*; and the charging and discharging in general, of coated glass, has been called the *Leyden Experiment*.

form, but the thickness of the glass, that makes it more or less fit to be charged: and the thinner it is, the greater charge it is capable of receiving; for the stronger in proportion is the power of the Electricity of one side, to cause a contrary Electricity on the opposite side.

How thick a glass plate or other Electric should be, to become incapable of being charged, hath not yet been ascertained.

A coated glass is capable of holding a greater charge in condensed air, than when charged under the usual pressure of the atmosphere.

If a coated glass plate, or phial, after being charged, be insulated, and only one of its sides be touched with some Conductor, that side will not part with its Electricity, because the Electricity of one side exists in consequence of the contrary Electricity on the opposite side, and both, by their mutual attraction, confine one another upon the surface of the glass. In order therefore to discharge that glass, both

its coatings must be touched at the same time, and connected with the earth: or by means of some Conductor a communication must be made between them; and in this case the discharge is said to be made through that Conductor.

When, in order to discharge a jar, one of its coatings is touched first with a Conductor, as for instance, with one end of a chain, nothing very particular in that case will appear*; but as soon as the other end of the chain comes within a sufficient distance of the other coating, a spark will be seen between the end of the chain, and that coating, accompanied with a noise, &c. just as when an excited Electric, or an electrified Conductor, is made to communicate with another Conductor; but the power, the light, and the report is in general much

* If one coating of a charged jar communicates with the earth while the other coating is exposed to the free air for some time, the charge of that jar will be silently and gradually dissipated; for while the Electricity of one side goes to the earth, the Electricity of the other is communicated to the air, which, as we observed before, is never an Electric.

greater

greater than that of a spark taken from a body simply electrified.

If the communication between the two sides of a charged jar be made by imperfect Conductors, as a slender piece of wood, a wet packthread, &c. the discharge will be made silently and without explosion.

It is remarkable, that the spark occasioned by the discharge of charged Electrics, although it is more dense, more powerful, and makes a greater report, yet is not so long as the spark drawn from an electrified Conductor.

When the discharge of a jar is made through the body of a living animal, it occasions a sudden motion, by contracting the muscles through which it passes, and gives a disagreeable sensation; for which reason, the effect of discharging an electric jar has been generally called the *electric Shock*. This shock is more sensibly felt by some persons than by others, and it is said that some people are not at all affected by it.

The

The force of the electric shock, occasioned by glasses of the same thickness, is greater or less in proportion to the quantity of coated surface, and the height of the charge. Upon this principle, the power of the said shock, by increasing the quantity of coated glass, may be augmented at pleasure, provided means be used powerful enough to charge it.

A number of coated jars connected together in such manner that their whole force may be united, and act like one jar, constitutes what is called an *electrical Battery*. This battery is the most formidable, and entertaining part of an electrical apparatus, and by its use many wonderful effects are produced:—but as the performing of these belongs rather to the practical, than to the present part of this Treatise, I shall only enumerate them in this place, and reserve further particulars for the third part of this work.

In making the discharge of an electric jar, it is surprizing to observe with what quickness the Electricity performs the circuit

cuit from one side of the glass to the other. It has been found to employ no perceivable time in going through a Conductor of several miles, which connected the two coatings of a phial*.

The force and noise of an electric shock is not affected by the inflexions of the Conductor, through which it goes, but it is sensibly weakened by its length; hence, when the circuit, *i. e.* the communication between the two sides of the electric phial, is made by one person touching one side with one hand, and the opposite side with the other, the shock is stronger than when the circuit is formed by many persons together joining hands.

That the Electricity finds some obstruction in going through even the best Conductors, appears evident, from this, that in some cases it will prefer a short passage through the air, to a long one through Conductors, even the most perfect. This obstruction is greater in those places, where the Conductors, forming the circuit, do not

* PRIESTLEY's Hist. of Elect. Per. VIII. Sect. ii.
lie

lie in perfect contact ; and if, the circuit being composed of Conductors of different natures, the Electricity be obliged to pass from one Conductor to another less perfect, the obstruction is still greater. If a small interruption of the circuit be made in water, on making the discharge (notwithstanding that the water is a Conductor) a spark will be seen in it, which never fails to agitate the water, and often breaks the vessel that contains it.

A strong shock, sent through an animal or a plant, puts an end to animal as well as to vegetable life. If the circuit be interrupted by one or more Electrics, or imperfect Conductors, of a moderate thickness, the electric shock will break them, and in some circumstances disperse them in every direction, and in such a manner as if the force proceeded from the center of every one of the interposed bodies *.

* In several instances the effect of a shock upon an interposed body is evidently greater on that side of it which communicates with that coating of the jar or battery, that is possessed of the positive Electricity. But of this more will be said hereafter.

A strong

A strong shock, sent through a slender piece of metal, makes it instantly red-hot, melts it, and, if the fusion is perfect, reduces it into globules of different magnitudes. If the metal be inclosed between pieces of glass, the shock, by melting it, will force it into the substance of the glass, so that afterwards it cannot be taken off without scraping part of the glass with it. In this experiment the glasses are shattered to pieces, and it is seldom that they resist the force of a strong shock.

If the glasses, inclosing the metal, be pressed by heavy weights, then a remarkable small shock is capable often not only to raise the weight, but to break such thick glasses, that otherwise require the force of a large battery. Thick pieces of glass may be also broken into innumerable fragments, by only sending a shock over a small part of their surface, which are pressed by weights, without the interposition of any metal. When these pieces of glass are not broken, they are marked by the explosion with the most lively prismatic colours, which lie sometimes confused, and sometimes

times in their prismatic order. The coloured spot is evidently formed by thin plates or scales, in part separated from the surface of the glass; and it generally occupies the space of about one inch in length, and half an inch in breadth.

In melting wires of the same metal by the electric shock, it must be observed, that the forces required for that purpose must be greater or less, according as the lengths or thicknesses of the wires are greater or less: but they are far from bearing any direct proportion to the quantity of metal; for if a wire of a given length and diameter be barely melted by a large battery, a wire of equal length and twice the substance, would perhaps take ten such batteries to produce the same effect upon it.

When a moderate shock * is sent through an imperfect metal (especially if the circuit is formed by several pieces, as by a chain),

* By a moderate shock here, I mean, one that is not able to melt the metal through which it passes.

a black

a black dust, in the form of smoke, will be seen to proceed from the metal, which is thought to be some of the metal itself partly calcined, and, by the violence of the explosion, forced from it.

If such circuit, or part of it, belaid upon a piece of paper, glass, or other Non-conductor, this, after the explosion, will be found stained with some indelible marks, and often shew evident signs of having been burnt. A long and permanent track may be marked upon glass, and some other bodies, by the electric explosion, if the interruption of the circuit be made upon its surface.

What is more remarkable, in considering the effects of Electricity on metals, is, that it revivifies their calces; and, like a true phlogistic process, when an explosion is made between two pieces of the same, they, in part, return into their metalline form.

Although we observed, in the fifth chapter, that Electricity and Magnetism did not interfere

interfere with one another's action, yet that must not be understood in general, and when a large force of Electricity is meant; for this is capable not only of destroying the virtue, or of reversing the poles of a magnetic needle, but even of giving it that virtue. When the charge of ten, eight, and even a less number of square feet of coated glass is sent through a fine sewing-needle, it will often give it polarity, so that it will traverse when laid on water *. It is remarkable, that if the needle be struck, lying east and west, that end of it which is entered by the shock, will afterwards point north; but if the needle be struck, lying north and south, that end of it which lay towards the north, will in any case point north; and the needle will acquire a stronger virtue in this, than in the former case. Lastly, if the needle is set perpendicular to the horizon, and the elec-

* A smart stroke of a hammer will make a needle magnetic: but they should always be tried before the experiment: for many small needles will traverse upon water, without the electric shock, or the stroke of the hammer.

tric

tric shock is given to either point of it, afterwards the lower extremity of the needle will point north*.

That the electric spark should kindle inflammable substances, I think might be expected, when its power has been considered in many circumstances, in which it has been observed to act as a most penetrating and extraordinary fire. In firing several substances a small shock is sufficient; and inflammable spirits may be fired even by a spark proceeding from an electrified Conductor.

If the moderate charge of a large battery is discharged between two smooth surfaces of metals, or semi-metals, lying at a small distance from each other, a beautiful spot will be marked upon them. This consists of one central spot, and some concentric circles †, which are more or less distinct,

* See Dr. FRANKLIN's Letters, p. 90, and BECCARIA's Artificial Electricity, § 731, 732, 733, 734.

† The central spot as well as the circles lie at a little distance from one another; and they are composed of dots and cavities, indicating a true fusion.

and more or less in number, according as the metal upon which they are marked, requires a less or greater degree of heat to be melted, and as a greater or less force is employed.

If the explosion of a battery, issuing from a pointed body, as the point of a needle, be repeatedly taken upon the plain surface of a piece of metal situated at a little distance from the point, or if issuing from the surface, be taken upon the point, that metal will be marked with a coloured spot, consisting of all the prismatic colours disposed in circles, and evidently formed by scales, or thin plates of the metal separated by the force of the explosion *.

When the discharge of a battery is made by bringing the ends of two Conductors, communicating with the inside, and the outside of the battery, in contact with, or at a little distance from the surface of several conducting substances, as water, raw meat, &c.

* For further particulars concerning those circles, see the Phil. Trans. vol. LVIII.

it is observable that the Electricity, instead of entering those substances, goes over their surface, and in a lucid separate body reaches from Conductor to Conductor; sometimes it prefers a much longer passage over the surface, to a shorter one through any substance. In this case the explosion never fails to give a concussion to the body, over whose surface it passes.

The electric explosion, or even electric sparks, when taken in different kinds of air, or permanently elastic fluid, was observed by Dr. PRIESTLEY to act like a true phlogistic process *. But upon a nicer examination, it seems that the phlogistic principle does not proceed from the electric fluid itself, but is detached, by the force of Electricity, from those Conductors, between which the explosions or sparks are taken †. It may be also mentioned in this place to have been

* See Dr. PRIESTLEY's second vol. of Observations on different kinds of air.

† See my Treatise on Air, and other permanently elastic Fluids, p. 433.

found by Dr. PRIESTLEY, that every kind of permanently elastic fluid is a Non-conductor of Electricity; but probably they are not all of the same degree. The colour of the electric spark, although equally visible, yet is not of the same colour in every sort of elastic fluid. In inflammable and in alkaline air, it appears of a purple or red colour; in fixed air it appears white.

The electric explosions taken upon the leaves of certain flowers, changes their colour*.

Besides the above-mentioned properties of charged glass, there are a few more observed, which as yet have neither been sufficiently investigated, nor so far pursued as to be reduced under any general laws. They afford a great field for speculation, and seem to be more intimately connected with the nature of Electrics in general; but it seems not proper to make any general conclusions from the facts already known, at least so as

† Dr. PRIESTLEY's Hist. of Electricity, Per. VII.

to be inserted in this part of the present treatise. I shall therefore employ a chapter for the narration of the same, in which I shall relate the principal, and more promising experiments hitherto made, and take notice of the best conjectures offered for their explanation. This chapter will be found at the end of the third part, in which place, I think, it will be more acceptable to my readers, particularly such, who have not been much conversant with Electricity, and therefore require first the description of the electrical apparatus, and the knowledge of the experiments necessary to prove the facts recited.

C H A P. VIII.

Of Atmospheric Electricity.

WHOEVER has remarked the numerous properties of Electricity already mentioned, and has considered their extensive power, will, I doubt not, be greatly surpris'd, when he compares the state, in which the science remained half a

century ago, with that in which it is at present; but his wonder will still increase, when he is told that Electricity is not only to be observed by rubbing an Electric, or warming a Tourmalin, but that it has been found to exist in the air, rain, and clouds: that thunder and lightning have been discovered to be its effects; and that, in short, whatever has the appearance of fire, or of any thing extraordinary in the atmosphere, and upon the earth, has been attributed to Electricity.

That the effects of Electricity bore a great resemblance to thunder and lightning, had been several times remarked by philosophers, and especially by the learned Abbé NOLLET; but that they should actually be found to be effects of the same cause, and that the phenomena of Electricity should be imitated by lightning, or those of lightning by Electricity, was neither thought possible, nor suspected, till the celebrated Dr. FRANKLIN made the bold assertion, and the French philosophers first, and afterwards Dr. FRANKLIN proved the fact by undeniable arguments in the year 1752.

The

The similarity of lightning and Electricity is not to be remarked in a few appearances only, but it is observable throughout all their numerous effects, and there is not a single phenomenon of the one, but may be imitated by the other. Lightning destroys edifices, animals, trees, &c.; lightning goes through the best Conductors, which it meets in its way, and, if its passage is obstructed by Electrics, or less perfect Conductors, it rends them, and disperses them in every direction; lightning burns, and melts metals and other substances; a stroke of lightning often disturbs the virtue of a magnet, and gives polarity to ferruginous substances; and all these effects, as has been observed above, may be produced by Electricity. But, independent of the great similarity existing between lightning and Electricity, what fully proves their identity is, that the matter of lightning may be actually brought down from the clouds by means of insulated and pointed metallic rods, or by electrical kites, and with it any known electrical experiment may be performed.

Clouds, as well as rain, snow, and hail, that fall from them, are almost always electrified, but oftener negatively than positively; and the lightning, accompanied with the thunder, is the effect of the Electricity, which, darting from a cloud, or a number of clouds, highly electrified, strikes into another cloud, or else upon the earth; in which case it prefers the most lofty and pointed places, and by this stroke produces all those dreadful effects, that are known to be occasioned by lightning.

The air, at some distance from houses, trees, masts of ships, &c. is generally electrified positively, particularly in frosty, clear, or foggy weather; but how the air, the fogs, and the clouds become electrified has not yet been ascertained, although several conjectures have been offered.

After that Electricity, and the matter of lightning were found to be the same thing, philosophers began to suspect the action of Electricity to be where it had before been less imagined, and not without reason endeavoured to reconcile to it several other natural

tural appearances. The aurora borealis, or northern light, was soon attributed to Electricity, on observing that by this that flaming light may be imitated *, and that the aurora borealis, when very strong, has been known to disturb the magnetic needle †, which is also an effect of Electricity.

The accentions, that are often seen in the atmosphere (commonly called *falling Stars*) are thought to be electrical appearances. The same is also supposed to be the cause of such other meteors like white clouds, that often appear by night-time, particularly in hot climates. Besides those phenomena, water-spouts, hurricanes, whirlwinds, and even earthquakes have been attributed to Electricity. But now, perhaps, the reader will think philosophers too extravagant, in going so far with Electricity.

* The late Mr. CANTON frequently collected Electricity in a considerable degree, during the time of an aurora borealis. His apparatus for that purpose consisted of an insulated fishing rod, erected on the top of his house, and having a wire twisted round.

† See the Phil. Trans. vol. LIX. page 88.

Such

Such thoughts seem at first sight to be extravagancies; but if it be considered, that they do not appear to contradict the known laws of nature, that they are not assertions absolutely void of proofs, add that they are the thoughts of great philosophers, then, I think, they may be admitted, at least so far as to be tried on proper occasions, and to be considered as the most plausible conjectures yet offered in explanation of the most surprizing phenomena of nature*.

* For further conjectures see Dr. FRANKLIN'S Letters, and Dr. PRIESTLEY'S Hist. of Elect.

C H A P. IX.

Advantages derived from Electricity.

NATURE, ever wise and admirable in her actions, seems to follow a certain similitude in her works with a conformity of operations, and, from the simplest to the most complicated of her objects, an analogy is observable, which, as it is wonderful to be considered, so it is instructive and useful. It is on account of this analogy, that whenever a discovery is made in any part of natural philosophy; whenever a science is advanced, we not only attain to the knowledge of that single law, or particular science, but at the same time acquire means in general of investigating the operations of nature with somewhat more certainty and accuracy, and by pursuing that analogy we are enabled to make further discoveries, and to improve every branch of knowledge. How far Electricity has contributed towards this purpose, I think is unnecessary to be further proved, when its
action

action has been shown to be so general, and so powerful, as to perform what no art can operate. But, besides the field that Electricity has opened for further discoveries, and the satisfaction of that curiosity, which before attended the contemplation of so many wonderful phenomena as have been explained by this science, there are two great advantages derived from Electricity; the one is a defence against the direful effects of lightning, and the other a remedy for many disorders incident to the human body.

In order to guard edifices or ships from being damaged by lightning, it was judiciously proposed, by Dr. FRANKLIN, to raise a metallic Conductor some feet above the highest part of the building, and continue it down the wall till it penetrated some feet into the ground; by this means the house could never receive any damage, for whenever the lightning should happen to fall upon it, it is evident that the Conductor, being of metal, and higher than any part of the building, would certainly attract it, and, by conducting it to the ground, hinder that building from receiving any damage; for

for it is known that Electricity always strikes the nearest and best Conductors, that it meets with in its way.

The reasonableness and truth of this assertion has been confirmed by numberless facts, and the practice of raising such Conductors has been found exceedingly useful, particularly in hot climates, where thunder-storms are very frequent, and the damages occasioned by the same, too often experienced.

In regard to the construction of such Conductors, there have been some controversies among Electricians; and the most advantageous manner of using them has not, without a great many experiments, and but very lately, been ascertained. Some philosophers have asserted that such Conductors should terminate in a blunt end, that they might the less invite the lightning from the clouds; for a blunt end will not attract Electricity from so great a distance as a sharp point. But some other philosophers have thought a pointed termination to be much preferable to a blunt one, and their assertion seems, on the following

lowing accounts, founded on much better reasoning.

A sharp-pointed Conductor, it is true, will attract Electricity from a greater distance than a blunt one, but at the same time, will attract and conduct it by little and little, or rather by a continued stream, in which manner a remarkably small Conductor is capable of conducting a very great quantity of Electricity; whereas a blunt-terminated Conductor attracts the Electricity in a full separate body, or explosion, in which manner it is often made red-hot, melted, and even exploded in smoke, and by such a quantity of Electricity, as perhaps would not have at all affected it, if it had been sharply pointed.

A sharp-pointed Conductor, certainly, invites the matter of lightning easier than a blunt one, but to invite, receive, and conduct it in small quantities never endangers the Conductor; and the object of fixing a Conductor to a house, is to protect the house from the effects of, and not the Conductor from transmitting the lightning.

It is an observation much in favour of sharp-pointed Conductors, that such steeples of churches, and edifices in general, as are terminated by pointed metallic ornaments, have very seldom been known to be struck by lightning, whereas others that have flat or blunt terminations, and have a great quantity of metal in a manner insulated on their tops, are often struck by it, and it is but seldom that they escape without great damage.

Besides those considerations, a sharp-pointed Conductor, by the same property of attracting Electricity more than a blunt one, may actually prevent a stroke of lightning *, to do which a blunt-ended one is absolutely incapable.

A Conductor therefore to guard a building, as it is now commonly used in consequence of several considerations, and ex-

* This and other properties of pointed Conductors will be made to appear very evidently by experiments.

periments, should consist of one iron rod * about three quarters of an inch thick, fastened to the wall of the building, not by iron cramps, but by wooden ones. If this Conductor was quite detached from the building, and supported by wooden posts at the distance of one or two feet from the wall, it would be much better for common edifices, but it is more particularly advisable for powder-magazines, powder-mills, and all such buildings as contain combustibles ready to take fire. The upper end of the Conductor should be terminated in a pyramidal form, with the edges, as well as the point, very sharp †; and if the Conductor is of iron, it should be gilt, or painted for the length of one or two feet. This sharp end should be elevated above the highest part of the building (as above a stack of chimnies, to which it may be

* Copper would do much better than iron for a Conductor; it being a more perfect Conductor of Electricity, and at the same time not being subject to contract rust as soon as iron.

† This pyramidal termination of the Conductor is an improvement of an ingenious Electrician, Mr. SWIFT at Greenwich.

fastened)

fastened) at least five or six feet. The lower end of the Conductor should be driven five or six feet into the ground, and in a direction leading from the foundations; or it would be better to connect it with the nearest piece of water, if any be at hand. If this conductor, on account of the difficulty of adapting it to the form of the building, cannot conveniently be made of one rod, then care should be taken, that where the pieces meet, they be made to come in as perfect contact with one another as possible; for, as we observed before, Electricity finds considerable obstruction where the Conductor is interrupted.

For an edifice of a moderate size, one Conductor, in the manner already described, is perhaps sufficient; but, in order to secure a large building from sustaining any damage by lightning, there should be two, three, or more Conductors, in proportion to the extent of the building.

On board ships a chain has often been used for this purpose, which, on account of its pliability, has been found very convenient,

venient, and easy to be managed among the rigging of the vessel ; but as the Electricity finds a great obstruction in going through the several links, for which reason chains have been actually broken by the lightning, so their use has now been almost intirely laid aside, and in their stead, copper wires a little thicker than a goose-quill have been substituted, and found to answer very well. One of these wires should be elevated two or three feet above the highest mast in the vessel ; this should be continued down the mast, as far as the deck, where, by bending, it should be adapted to the surface of such parts, over which it may most conveniently be placed, and, by continuing it down the side of the vessel, it should be always made to communicate with the water of the sea.

In regard to personal security, in case a thunder-storm were to happen while a person is in a house not furnished with a proper Conductor, it is adviseable not to stand near places where there is any metal, as chimnies, gilt frames, iron casements, or the like ; but to go into the middle of a
room,

room, and endeavour to stand or sit upon the best Non-conductor that can be found at hand, as an old chair, a stool, &c. “ It
“ is still safer (says Dr. FRANKLIN) to
“ bring two or three matresses or beds into
“ the middle of the room, and, folding
“ them up double, put the chair upon
“ them; for, they not being so good Con-
“ ductors as the walls, the lightning will
“ not choose an interrupted course through
“ the air of the room and the bedding,
“ when it can go through a continued
“ better Conductor, the wall. But where
“ it can be had, a hammock or swinging
“ bed, suspended by silk cords, equally
“ distant from the walls on every side, and
“ from the ceiling and floor above and be-
“ low, affords the safest situation a person
“ can have in any room whatever, and
“ what indeed may be deemed quite free
“ from danger of any stroke by lightning.”

If a storm was to happen whilst a person is in the open fields, and far from any building, the best thing he can do is to retire within a small distance of the highest tree or trees he can get at; he must by no

means go quite near them, but should stop at about fifteen or twenty feet from their outermost branches ; for if the lightning should fall thereabout, it will very probably strike the trees ; and in case a tree was to be split, he is safe enough at that distance from it.

In regard to the other great use of Electricity, *viz.* its application as a medicine, there have been many opinions *pro* and *contra*, and the reputation of medical Electricity has been very dubious and fluctuating ; owing to the exaggerations, the mistakes, the prejudices, and the interest of those who have administered it in physical cases. But after many experiments, and after overcoming the rooted prejudice of several physicians against medical Electricity, it has been clearly observed, that, when properly managed, it is an harmless remedy, which sometimes instantaneously removes divers complaints, generally relieves and often perfectly cures various disorders, some of which could not be removed by the utmost endeavours of physicians and surgeons.

It

It is an important remark, that Electricity, when properly managed, if it does not effect a cure, at least it produces no bad effect; the few cases in which it seems to have produced any harm, are of a doubtful nature. In order, however, to satisfy more fully the curiosity of the reader about this important subject, I shall here subjoin two cases, in one of which, related by Dr. HART of Shrewsbury, the application of Electricity proved very pernicious; and the other is a most remarkable instance of its good effect. In regard to the first case, it is thought by some, that Electricity was injudiciously applied; but of the veracity and just treatment of the second the reader can have no doubt, for it was executed by the celebrated Dr. WATSON, a gentleman, who is both an excellent physician, and one of the greatest Electricians.

C A S E I.

“ A young girl, about sixteen, whose
“ right arm was paralytic, on being elec-
“ trified the second time, became univer-
“ sally

“ fally paralytic, and remained so about a
 “ fortnight, when the increased palsy was
 “ removed by medicines, which her case
 “ indicated; but the first diseased arm re-
 “ mained as before: I should have men-
 “ tioned too, that this arm was greatly
 “ wasted, in comparison to the other.
 “ However, notwithstanding the former bad
 “ accident, I had a mind to try the effect
 “ of Electricity on her again; which we
 “ renewed, and, after about three or four
 “ days use, she became the second time
 “ universally paralytic, and even lost her
 “ voice, and with difficulty could swallow.
 “ This confirmed me in my opinion, that
 “ the electrical shocks had occasioned these
 “ symptoms.—We therefore omitted it,
 “ and the girl, though she grew better of
 “ her additional palsy, for so I call it, re-
 “ mained as bad as before of her first *.”

C A S E II.

A girl belonging to the Foundling Hos-
pital, aged about seven years, being first

♦ Phil. Transf. Vol. XLVIII.

seized

seized with a disorder occasioned by the worms, was at last, by a universal rigidity of the muscles, reduced to such a state, that her body seemed rather dead than alive. After other medicines had been ineffectually administered for about one month, she was at last electrified intermittedly for about two months; after which time she was so far recovered, that she could, without pain, exercise every muscle of her body, and perform every action as well as before she had the distemper †.

The remarks made by philosophers, relating to the effects of Electricity upon the human body in general, are the following; *viz.* that by electrization, whether positive or negative, the pulse of a person is quickened, the number of pulsations being generally increased about one sixth; and that glandular secretions, and the insensible perspiration, are promoted, and often even restored, when they had been entirely obstructed. These effects may be proved by several experiments, independent of physi-

† Phil. Trans. Vol. LIII;

cal cases; and I think there is nobody who will deny, that such promotions are not only beneficial, but absolutely necessary for removing several disorders. It might be naturally suspected, that the promotion of perspiration, and of glandular secretion, were only the consequence of the accelerated pulsation, and not the immediate effect of Electricity: but the contrary is easily proved, by observing, that in various cases, the quickening of the pulsation by other means, independent of Electricity, as fear, exercise, &c. did not promote those secretions nearly so much, if at all, as electrization; and also, that glandular secretion and perspiration are often promoted by Electricity, when applied only to a particular part of the body, in which case it seldom, if ever, accelerates the pulsation.

Hitherto it has not been discovered, that the electric fluid acts within the human body by any chymical property, as most medicines generally do; but its action, by which it produces the above-mentioned effects, may be considered merely as a mechanical stimulus; for it seems to act as such, even
 9 within

within those parts of the body, which, especially when diseased, are mostly out of the reach of other remedies,

Formerly, in order to stimulate, or in general to apply Electricity to any diseased part of the human body, strong shocks, or at least very pungent sparks, were thought necessary; but at present it is very reasonably established, upon experience, that the greatest electric powers which can be applied with good expectations, are exceedingly small shocks and moderate sparks, the proper force of which will be particularly described in the sequel; but that in general, the most proper treatment is, to throw the fluid by means of a wooden point, as it is commonly called, or merely by a metallic point; in which last case, the person electrified feels only a gentle wind upon that part of the body towards which the point is directed.

By considering the above-mentioned effects of Electricity, one may naturally suspect, that in cases of preternatural discharges, the application of Electricity would
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be rather injurious than beneficial; because in those cases the discharge is required to be suppressed, and not promoted. In respect to this important point, it has been observed, that if strong shocks, or very pungent sparks, are given to the patients afflicted with those discharges, the disease is seldom cured, and on the contrary is often increased; but when only the fluid is drawn from the part, by means of a wooden point, or at most exceedingly small shocks are administered, when the seat of the disease is more internal, then the discharge, &c. is at first generally promoted for a few days or hours, according to the nature of the disease and other circumstances, but afterwards it lessens by degrees, till it is quite cured. In cutaneous eruptions, the application of Electricity is generally attended with similar effects.—The eruption first spreads farther for a short time, and afterwards lessens by degrees till it quite vanishes. From these observations it appears, that the application of Electricity, when judiciously managed, does not merely promote any discharge or circulation of fluids, but rather assists the *vis vitæ*, or that innate

innate endeavour, by which nature tends to restore the sound state of the injured parts of a living animal.

It may perhaps be ever difficult to explain in what manner Electricity assists that natural endeavour; but experience shews the certainty of the fact, and with it we must be gratefully contented; for we may apply the effects to our wants, though we are ignorant of their cause, and of its mode of acting. When an electric shock is sent through any part of the body, an instantaneous involuntary motion or convulsion is occasioned, which shews that the muscular fibres through which the shock is sent, are expanded, or in some other manner convulsed. This involuntary motion, though not so strongly, is occasioned also by sparks, and often even by drawing the fluid.—Farther, when a shock is sent through or over several substances besides the human body, a tremulous motion and an expansion is evidently occasioned, as may be shewn by many electrical experiments. Now all these observations may perhaps, in a manner, explain

plain the action of Electricity upon the organized parts of an animal body, by comparing it with the tremulous motion given to pipes of any sort, through which fluids are transmitted, in order to accelerate their passage, and to prevent any stoppage, which might arise from stagnation or accumulation of gross bodies. Perhaps the reason why strong shocks are generally hurtful, may be because the irritation they give to the obstructed parts, especially when they are very minute and delicate, breaks their organization; the force being greater than those parts can naturally bear.

Independent of undeniable practical observations, when it is only admitted that Electricity promotes natural secretions and circulation, which it certainly does, there follows, that its application must be beneficial in cases of unnatural discharges; for in those cases the discharge is occasioned by the obstruction of the natural ways; but Electricity removes those obstructions, which is the same thing as to promote natural secretion and circulation; therefore, it must suppress the unnatural discharge,

discharge, which can no longer exist when the natural course of the fluids has been restored.

With respect to diseases in general, two states of the affected parts should be considered. The first is, the immediate and recent cause of the disease; and the second state is, the alteration of other parts, especially solid, which is occasioned by the long continuance of the first and principal cause; thus, for instance, the weakness or rupture of some vessels within the body, may occasion extravasation of fluids, which is the first state of the disease. Now if these extravasated fluids continue in any part of the body, they will gradually occasion a suppuration, an inflammation, or other symptoms, which vary according to innumerable circumstances. This we may consider as the second state of the disease. Again, when a palsy deprives a part of the body of its motion, the fleshy and even the more solid parts, in process of time, waste and become disfigured; which is the effect of the obstructed motion and circulation, and which we may therefore consider as
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the second state of the disease; and so of the rest. Now it has been observed, that the power of Electricity often removes the first state of the disorder; but the latter is very seldom cured by it. Indeed it seems almost impossible that a disfigured bone or destroyed organization should be restored to its sound state by means of Electricity. Dr. FRANKLIN having electrified several paralytic persons in America, observed that they were generally relieved for a few days at the beginning, but that they afterwards either did not mend, or relapsed into the state, they were before the use of Electricity*. Here it must be observed, that those paralyties were mostly of a long standing, and also that the method practised by the Doctor, was to give strong shocks, which we have already remarked to be rather prejudicial.

In general, the application of Electricity has been found to be of very little use in cases of long standing; because, as we ob-

* See Dr. FRANKLIN's Philosophical Letters, Papers, &c. and Dr. PRIESTLEY's Hist. of Electricity.

served above, the more solid parts, by the long continuance of the disorder, have undergone such alteration, as cannot be restored by a mere stimulus, such as the electric action is supposed to be. However, sometimes diseases of many years standing have been perfectly cured by means of Electricity. In these cases therefore, although there may be less hope of effecting a cure, it is not improper to apply the power of Electricity, which, when judiciously managed, does never produce any bad effects.

Hitherto, I do not know that any authentic facts have shewn any difference between the application of different kinds of Electricity, in medical cases. Whether the patients be electrified by the prime Conductor, or the insulated rubber of the usual electrical machines, *viz.* whether they are electrified positively or negatively, seems to be quite indifferent.

In respect to the cases in which Electricity may be applied; experience shews, that in general, all kinds of obstructions, whether

whether of motion, or circulation, or of secretion, are very often removed or alleviated by Electricity. The same may be also said of nervous disorders; both which include a great variety of diseases. The application of Electricity has seldom entirely cured diseases of a long standing, although it generally relieves them. To persons afflicted with the venereal disease, or to pregnant women, electrization has been thought to be pernicious; but my reader may be assured, that even in those cases it may be used without fear, if it is judiciously managed. When pregnant women are to be electrified for any disorder, the shocks should be absolutely forbidden; and even when the other more gentle treatments are used, a constant attention should be given to any phenomenon that may appear in the course of the electrization; the method of which should be increased, diminished, or suspended, according as circumstances may indicate.

Having thus given a summary view of the theory of medical Electricity, without entering into the detail of many physical cases,

cases, I shall reserve to say something of the practical part, for the third part of this work; whilst I must refer the reader, that is desirous of knowing further particulars relating to medical Electricity, to my Essay on that subject, or to the works of others *.

C H A P. X.

Containing a compendious view of the principal properties of Electricity.

AFTER the laws hitherto established in the science of Electricity have been exhibited at large, and the particulars relating to each have been sufficiently considered, it will not be amiss to show in how

* Abundance of physical cases, in which Electricity has been applied, may be met with in almost every writer on Electricity, but especially in JAL-LABERT's *Experimenta Electrica*, LOVETT's *Subtil Medium proved*, WESLEY's *Desideratum*, or *Electricity made plain and useful*, FERGUSON's *Introduction to Electricity*, and BECKET's *Essay on Electricity*. Some cases in which Electricity has been successfully applied for the amaurosis are also related in the 3d and 5th Vol. of the *Medical Essays*.

small a compass those laws may be reduced, and how narrow is the foundation of all that has hitherto been done.

I doubt not but this recapitulation will prove very serviceable to those, who are novices in Electricity, as, by getting in memory a few particulars, they will not only reconcile all that has been said before, but also be enabled themselves to explain most of the following experiments, and to understand the application of the hypothesis, of which we shall next proceed to treat.

All the natural bodies are divided into two classes, *i. e.* Electrics and Conductors. Electrics are such as may by some means be excited, so as to produce Electrical appearances; but Conductors are such as cannot be excited by themselves, *i. e.* without the interference of an Electric: further, electrical substances will not transmit Electricity, whereas the substance of Conductors is pervaded by it.

Electrics may be excited three ways, *i. e.* by friction, by heating and cooling, and by melting,

melting, or pouring one melted substance into another.

When two different bodies, except they are both Conductors, are rubbed together, they will both (provided that which is a Conductor be insulated) appear electrified, and possessed of different Electricities; so when a piece of smooth glass is rubbed with an insulated piece of leather, it acquires one kind of Electricity, called the vitreous, positive or plus Electricity; and the insulated leather acquires the other, called the resinous, negative or minus Electricity.

The difference between these two Electricities consists principally in the appearances of their light, and in the phenomena of attraction and repulsion.

When the positive Electricity is entering a pointed body, it causes in general the appearance of a lucid star or globule on that point; but the negative Electricity generally shows a lucid pencil of rays seeming to issue from the extremity of the pointed body.

Bodies, possessed of the same Electricity, repel each other; but bodies, possessed of different Electricities, attract each other.

Whenever bodies of any kind come within the sphere of action of an electrified body, except they are very small, and insulated, they become actually possessed of the Electricity contrary to that of the electrified body, to which they are presented.

No Electricity can be observed upon the surface of any electrified body, except that surface is contiguous to an Electric, which Electric can somehow or other acquire a contrary Electricity at a little distance. Otherwise,—no Electricity can appear upon the surface of any electrified body, except that surface is opposite to another body, which has actually acquired the contrary Electricity, and these contrarily electrified bodies are separated by an Electric*.

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* On considering this principle, it may be asked, why any Electricity can be observed upon the surface of an electrified body, that is insulated at a considerable distance from other Conductors? Or, which is

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If the repulsion existing between bodies possessed of the same kind of Electricity be excepted, all the other electrical phenomena are occasioned by the passage of Electricity from one body to another.

A considerable quantity of Electricity exists in the atmosphere, and is certainly employed for some great purposes of nature.

the Electric, that is contiguous to the surface of an electrified Conductor, or excited Electric, and which has actually acquired a contrary Electricity at a little distance from the said surface? To this question is answered, that the air is in general the Electric, which is opposite to the surface of any electrified body, which being not a perfect Conductor, does easily acquire a contrary Electricity on a stratum of its substance, that is at a little distance from the electrified body; and in consequence of this stratum, it acquires another stratum contrarily electrified, and at a little distance from the former; to this, other strata succeed, alternately possessed of positive and negative Electricities, and decreasing in power until they vanish, or come to the walls of the room, &c. Consider the experiment of the glass tube, mentioned in the VIth chapter, which shows that, in general, when an Electric, sufficiently dense, is presented to an electrified body, it acquires successive zones, or strata of positive and negative Electricity.

Hitherto Electricity has not been found concerned in any fermentation, evaporation, or coagulation, although the clouds, the rain, the hail, the snow and the fogs, are almost always electrified.

These few laws, well considered, will be found to contain almost all that is known of the subject, and if properly applied, they may explain most of the experiments that follow.

Besides what has been said in this part of the present Treatise, there are several other maxims, rules, &c. to be known in Electricity; but as these mostly respect the real practice, so they will be occasionally inserted in other places, that seem better adapted to their reception.

PART II.

THEORY OF ELECTRICITY.

CHAP. I.

The Hypothesis of Positive and Negative Electricity.

IT is the business of Philosophy to collect the history of appearances, and from these to deduce such mechanical laws, as may either be themselves of immediate use, or lead to the discovery of other facts more interesting and necessary for the happiness of human kind. After a number of such constant appearances, which are called natural laws, have been established, and confirmed by a sufficient number of experiments, it is then proper to investigate the cause of those effects; which, if it is once discovered, and its mode of acting is ascertained, puts an end to the trouble of experimental investigation, and renders the application of its effects certain, and determinate.

Causes and effects are so intimately connected and dependent on each other, that throughout the system of nature we everywhere discover a series of energies, which whilst they are depending on, and derived from, their preceding terms, are at the same time the causes of their succeeding ones. But what is the first cause of all the rest, which being not the effect of any preceding, may be called the source of all, and the first term in the series? In contemplating this source, the mind is lost in wonder, and, after we are advanced a few steps, we find that a cloud obstructs our further progress, and, from continuing our inquiry and contemplation, nothing more can be derived but an argument to prove the imbecillity and shortness of our understanding. This however is not the subject of the present Treatise; and all I meant to deduce is, that, after the laws of Electricity have been considered, it is necessary that we should go a little further, and investigate, if possible, the immediate cause of that property in nature, or consider the most probable conjectures that have been offered on this subject: by the knowledge of which we may explain all
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the known electrical appearances, and adapt their effects to our purposes with somewhat more certainty and precision.

The vast number of hypotheses that have been framed in explaining the electrical phenomena, from the infancy of the science to the present time, may be easily imagined, by considering the great number of labourers, and the discoveries that have been produced without intermission in this field of wonders. It would be not only an endless work to relate all the hypotheses hitherto offered, but also an useless one, when they have been evidently contradicted by several experiments, and after they have all given place to the hypothesis of a single electric fluid, which generally goes under the name of Dr. FRANKLIN'S. That although this hypothesis explains all the known electrical appearances, it is however not a demonstrable truth, but the most probable supposition, I confess; and, in order that a due distinction might be preserved between the knowledge of facts, and the supposition of their immediate cause, I have separated the former from the latter, and followed that
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method which seemed more philosophical and instructive; but now to make further apologies for admitting this hypothesis, at a time when numberless experiments speak clear in its favour, would be doing an injury to the philosophical world in general, and especially to the ingenious philosophers that proposed and improved it. I shall therefore, without further preamble, lay it down as it is now commonly and reasonably admitted; and shall use it in the explanation of the following experiments.

All the phenomena called Electrical are supposed to be effected by an invisible subtile fluid existing in all the bodies of the earth. It is supposed also that this fluid is very elastic, *i. e.* repulsive of its own particles, but attractive of the particles of other matter.

When a body does not show any electrical appearances, it is then supposed to contain its natural quantity of electric fluid (but whether that quantity bears any proportion to the quantity of matter in general, or not, is uncertain), and therefore that body is

said to be in its *natural*, or *non-electrified state*: but if a body shows any electrical appearances, it is then said to be electrified, and it is supposed that it has either acquired an additional quantity of electric fluid, or that it has lost some of its natural share. A body having received an additional quantity of electric fluid, is said to be *overcharged*, or *positively electrified*; and a body that has lost part of its natural quantity of electric fluid, is said to be *undercharged*, or *negatively electrified*.

From hence it appears, why the terms *positive* and *negative*, or *plus* and *minus* Electricity came to be used; for the first signifies a real plus, or superfluity, and the second a real minus, or deficiency of the quantity of electric fluid proper to a body.

By this hypothesis, which is analogous to the other phenomena of nature, the electrical appearances are easily explained, and there is not a single experiment that seems to contradict it. First it appears, that when an electric and a conducting substance are rubbed together, the Electricity is not then
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produced, but by the action of rubbing one body pumps, as it were, the electric fluid from the other*: hence, if one becomes overcharged with it, or positively electrified, the other must necessarily be undercharged,

* By what mechanism one body extracts the electric fluid from the other is not yet known. The celebrated Father BECCARIA supposes that the action of rubbing increaseth the capacity of the Electric, *i. e.* renders that part of the Electric, which is actually under the rubber, capable of containing a greater quantity of electric fluid; hence it receives from the rubber an additional share of fluid: which is manifested upon the surface of the Electric, when that surface is come out of the rubber; in which state it loses, or, as it were, contracts its capacity. Signior BECCARIA's experiment to prove this supposition is the following:—He caused a glass plate to be rubbed by a rubber applied on one side of the plate, while it was turning vertically; and holding at the same time a linen thread on the other side of the plate, just opposite to the rubber, he observed, that the thread was not attracted by that part of the glass which corresponded to the rubber, but by that which was opposite to the surface of the glass that had just come out of the rubber; which shows that the fluid, acquired by the glass plate, did not manifest its power until the surface of the glass was come out of the rubber. But, query, in what manner does the glass augment its capacity of holding the electric fluid by the action of the rubber? See Dr. FRANKLIN's Letters, &c. § 34.

or electrified negatively, except its deficiency be supplied by other bodies communicating with it. From hence also appears the reason, why, when an Electric is rubbed with an insulated rubber, it can acquire but little Electricity; because in that case, the rubber, not communicating with other Conductors, can supply the Electric with only that small quantity of fluid which belongs to itself, or which it collects from the contiguous air.

Electric attraction is easily explained; for this does not exist, except between bodies differently electrified; which must certainly attract each other, on account of the attraction existing between the superfluous electric fluid of the bodies electrified positively, and the undercharged matter of the bodies electrified negatively.

As to the repulsion existing between bodies possessed of the same Electricity; in order to understand its explanation thoroughly, the reader must be reminded of the principle mentioned in the preceding part, which is, that no Electricity, *i. e.* the electric fluid proper to a body, can either be augmented or diminished upon the surface
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of that body, except the said surface is contiguous to an Electric, which can acquire a contrary Electricity at a little distance; from whence it follows, that no Electricity can be displayed upon the facing surfaces of two bodies that are sufficiently near one another, and both possessed of the same Electricity; for the air that lays between those contiguous surfaces has no liberty of acquiring any contrary Electricity. This being premised, the explanation of electric repulsion becomes very easy. Suppose, for instance, that two small bodies are freely suspended by insulated threads, so that when they are not electrified they may hang contiguous to one another. Now suppose those bodies to be electrified either positively or negatively, and then they must repel one another; for either the increased, or the diminished natural quantity of electric fluid in those bodies, will endeavour to diffuse itself equally over every part of the surfaces of those bodies, and this endeavour will cause the said bodies to recede from each other, so that a quantity of air may be interposed between their surfaces, sufficient to acquire a contrary Electricity at a little distance from the said surfaces.—Otherwise, if the bodies, possessed of the same Electricity,

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city, do not repel each other, so that a sufficient quantity of air may be interposed between their surfaces, the increased quantity of electric fluid, when the bodies are electrified positively, or the remnant of it, when the bodies are electrified negatively, by the above principle, cannot be diffused equally throughout, or over the surfaces of those bodies; for no Electricity can appear upon the surfaces of bodies in contact, or that are very near one another. But the electric fluid, by attracting the particles of matter, endeavours to diffuse itself equally throughout, or over the surfaces of those bodies; therefore the said bodies are, by this endeavour, forced to repel one another.

I think it is unnecessary to insist further upon the above explanation; for the principle, upon which it depends, seems universal and clear, so that it may be easily applied to explain electric repulsion in general, as well as the repulsion between the above-mentioned two bodies.

The charging of coated glass, and other Electrics, as well as the other phenomena of Electricity, may also be easily accounted for
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by the above-mentioned hypothesis of Electricity ; but, I think it unnecessary to enumerate, and account for all the particulars in this place, as we shall have occasion to speak of them in the explanation of the experiments in the third part.

C H A P. II.

Of the Nature of the electric Fluid.

THE human mind, never satisfied, after the cause of some effects has been discovered, or only guessed at, attempts to investigate some more intimate quality, and even the origin of that supposed cause, making further suppositions, and framing other hypotheses, which, by the course of things, must certainly be less probable than the former. This unlimited endeavour to acquire knowledge is often too ridiculous to be pursued, on account of its abstruseness and uncertainty, especially when the steps immediately preceding the subject in hand have but a small degree of probability. It is from hence that Philosophers have frequently spent a great deal of time, and trouble in attempting to discover the properties
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and causes of what existed only in their own imaginations. Sometimes, however, when a supposed existence comes so very near to truth, that the most sceptic Philosopher hesitates not to confess the probability of it, or when he can invent no argument to evince the contrary, then it is not only allowable, but necessary for the business of Philosophy, to pursue the enquiry further, and, if nothing else can be ascertained, at least to propose some further conjectures upon the former hypothesis. This now is the case in the science of Electricity; and after we have related the most plausible hypothesis as yet offered, *i. e.* that of a single elastic fluid, we come in this place to consider the essence of this fluid, in order, if possible, that we might attain to, at least, some probable conjecture respecting its materials.

When nothing more than electric attraction and repulsion had been observed, Electricians supposed that these were effected by a kind of unctuous effluvia proceeding immediately from the electrified body; but when the light, the burning quality, the phosphoreal smell, &c. was perceived to be

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produced

produced by excited Electrics, then it was naturally supposed, that the electric fluid was of the same nature with fire. This opinion has prevailed much among several Philosophers, and it is from hence, that the electric fluid has been commonly called Electric Fire. Besides this supposed identity of the electric fluid, and the element of fire, there have been two other opinions concerning the essence of this fluid; it having been thought by some to be the ether of Sir ISAAC NEWTON, and by others (whose opinion seems to be the most probable) to be a fluid *sui generis*, i. e. different from all other known fluids.

In order the more regularly to examine these conjectures, it will be necessary to premise something in regard to the nature of fire, at least so much as is sufficient for the present purpose.

The element of fire may be considered in regard to its spring, to the different states of its existence, and to its effects. In regard to its origin it is commonly specified under the names of Celestial, Subterraneous, and Culinary

linary Fire ; understanding by the first, that, which proceeds from the sun, and, by being dispersed throughout the universe, gives life, and motion to almost every thing that exists ; by the second, that, which is the cause of volcanos, hot springs, &c. and lastly, under the name of Culinary Fire, understanding that, which is commonly produced upon the earth, by burning several substances. These distinctions however are little if at all useful ; for, whatever be the origin of fire, its effects are always the same.

In respect to the different states of its existence, the Chymists know only two ; the first obvious one, and indeed that, to which only is given the name of Fire, is that actual agitation of the particles of that element, which produces the complex idea of lucid, hot, &c. that is commonly understood under the name *Fire* ; and the other state is the real principle of fire existing as a constituent principle in several, and perhaps all substances ; or, that matter, whose particles, when agitated in a peculiar and violent manner, produce the common sensible fire.

This, which we may call fire in an unactive state, is the *Phlogiston* of the Chymists, and is that, which when united in a sufficient quantity with other substances, renders them inflammable. That this principle does really exist, is beyond a doubt; we may transfer it from one body to another; we may render a body inflammable, which in its own nature is not so, by superinducing on it the phlogiston; and we may reduce a body naturally inflammable, to a substance not inflammable, by depriving it of its phlogiston.

Now the electric fluid, as far as we can determine, bears but a very small resemblance to the above-mentioned two states of fire; for although it exists in different bodies, as the phlogiston, yet when we compare its other attributes with those of fire, we then immediately perceive it to be not the same, but a different principle. In the first place, if they were both the same thing, they should be always together, and whenever such a quantity of fire exists, there the same quantity of electric fluid should be found: but this is contrary to experiments; for a piece of metal or other substance may
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acquire a great degree of heat without appearing at all electrified ; and on the other hand, may be strongly electrified without acquiring by it any sensible degree of heat, or any addition to its phlogiston. Secondly, fire penetrates every known substance, and an exceedingly small quantity of it is diffused alike throughout bodies of every kind ; whereas the electric fluid pervades only Conductors *. Thirdly, the electric fluid goes through a very long Conductor in a space of time almost instantaneous ; but fire is very slowly propagated. I might enumerate several other improprieties attending this hypothesis of the sameness of fire and the electric fluid, but those already mentioned are, I think, sufficient to induce my readers to suppose otherwise.

Dr. PRIESTLEY, on observing that the electric explosion, taken in different kinds of air, acts, in general, like other phlogistic

* Here may be observed, that heat pervades more easily the substance of some good Conductors of Electricity ; but the rule however is far from being general.

processes, supposes that the electric matter either is, or contains, phlogiston †. In regard to this, I would observe, that there is no necessity of supposing the electric matter either to be, or contain phlogiston, on that account; for the phlogiston, in this case, may, by the force of the electric explosion, be extricated, either from the surface of the Conductors, between which the explosion is taken, or from particles of heterogeneous matter floating in that air, in which the explosion is made §.

In regard to the similarity between the effects of fire, and the effects of the electric fluid, it will be very obvious to remark, that although fire is in several instances produced by the electric fluid, yet we should never confound the one with the other, and consider them both as the same thing; for it is well known that friction produces fire, and it is by no means surprising that the electric fluid, by the rapidity of its motion,

† Observations on different Kinds of Air, vol. II, sec. XIII.

§ See my Treatise on Air, &c. p. 433.

through

through substances, that in some manner obstruct its passage, should generate light, heat, rarefaction, and the other effects of fire *.

Mr. HENLY, in consequence of several very interesting experiments, that he has lately made, supposes, that, although the electric fluid may be neither phlogiston nor fire, yet that it is a modification of that element, which, while in a quiescent state, is called Phlogiston, and when violently agitated is called Fire. We constantly observe (says he) I. that if two bodies are rubbed together, which have an equal quantity of phlogiston (which is the case with bodies of the same kind, as glass and glass, metal and metal, &c.) they acquire either very little, or no Electricity at all. II. That as one of the bodies has a greater quantity of phlogiston than the other, so they acquire a greater quantity of Electricity, as when glass is rubbed with metal.

* Here it is proper to observe, that the electric fluid shows no effects of fire, except when it goes through some medium that obstructs its free passage.

III. That a certain degree of friction produces Electricity, and that *a more violent friction produces fire*, but no Electricity, as may be observed by rubbing together two pieces of baked wood, of glass, &c. IV. And that in general, bodies, possessed of a greater quantity of phlogiston, give the electric fluid to bodies that have less of it, *i. e.* they acquire the negative Electricity, when rubbed with bodies that have a less quantity of phlogiston*.

From these observations we gather, that the electric fluid, and fire, are produced by

* Mr. HENLY, in order to try what Electricity different substances would acquire, insulated them upon sticks of sealing wax, and rubbed them against his woollen coat, or waistcoat. In this manner he tried a vast number of vegetable, animal, mineral, and artificial substances; and he discovered a very remarkable law, which is, that such substances, which have a great quantity of phlogiston, as vegetable substances, and particularly the hot, aromatic plants and seeds, &c. *give* the electric fluid; that is, they acquire the negative Electricity when rubbed against woollen cloths; and, that such substances, which have but little phlogiston (as most animal substances) *acquire* the electric fluid from the said cloths, *i. e.* they are electrified positively. See the Phil. Transf. for the year 1777.

similar

similar operations, and are both extracted from bodies abounding with phlogiston: and hence he concludes, that, the phlogiston, the electric fluid, and fire, are only different modifications of the very same element; the first being its quiescent state of existence, the second its first active, and the last its more violent state of agitation; like fermentation producing first wine, secondly vinegar, lastly putrefaction.

I shall only observe further on this ingenious hypothesis, in order to show its great degree of probability, that it is so very analogous to the other operations of nature, and at the same time so clear, and simple, that I think it can hardly be disregarded by the most prejudiced Philosopher.

As to the identity of the Electric, and the ethereal fluid, it seems to me quite an improbable, or rather a futile, and insignificant hypothesis; for this ether is not a real, existing, but merely an *hypothetical fluid*, supposed by different Philosophers to be endued with different properties, and to be an element of several principles. Some
suppose

suppose it to be the element of fire itself, others make it the cause of attraction, others again derive animal spirits from it, &c.; but the truth is, that not only the essence, or properties, of this fluid, but even the reality of its existence is absolutely unknown.

According to Sir ISAAC NEWTON's supposition, this ether is an exceedingly subtle, and elastic fluid, dispersed throughout all the universe, and whose particles repel the particles of other matter. But on this supposition the electric fluid is different from ether; for, although the former is subtle, and elastic, like the latter, yet (as Dr. PRIESTLEY observes) it is not repulsive like the ether, but attractive of all other matter.

C H A P. III.

Of the Nature of Electrics and Conductors.

THE remarkable difference existing between the two classes of bodies in regard to Electricity, *i. e.* Electrics and Conductors, naturally induces an Electrician to inquire what is that principle in bodies, or by what mechanism some substances become capable of transmitting the electric fluid, whilst others are impervious to it?

In regard to the explanation of these two remarkable properties, there have been, as might be expected, several conjectures offered; but, except one probable hypothesis, there is nothing as yet ascertained. When the catalogue of Electrics and Conductors was very short and imperfect, it was supposed that, the only two conducting principles were metals, and water; and that all substances were nearer, or further from the nature of a perfect Conductor, in proportion as they contained a greater or less quantity

tity of the above principles in their composition. Wood, for instance, was supposed to be a Conductor only on account of the water it contained within its pores; accordingly, it was observed, that the greater quantity of moisture the wood contained, the better Conductor it proved to be, and on the contrary, that it acted more like an Electric, in proportion as it was freed from its moisture. But when water itself was observed to be a bad Conductor, and hot air, and charcoal to be good Conductors, especially the latter, which substances, it is well known, contain no water nor metal, at least not in such a quantity as is sufficient to change a non-conducting substance into a Conductor, then the former supposition was laid aside, and another was offered by Dr. PRIESTLEY, in his second volume of Observations on the different Kinds of Air *, which seems to be well founded.

The Doctor, considering what the principle is, which Conductors possess in com-

* Sec. XIV.

mon, and finding one of their common ingredients to be the phlogiston, deduces from thence, that the conducting quality is absolutely owing to the phlogiston. “ Had there been (says he) any phlogiston “ in water, I should have concluded, that “ there had been no conducting power in “ nature; but in consequence of some “ union of this principle with some base. “ In this, metals and charcoal exactly “ agree:—while they have the phlogiston, “ they conduct; when deprived of it, they “ will not conduct.”

And in a note to this paragraph, he sub-joins:

“ Having since found, that long agitation “ in the purest water injures air, so that “ a candle will not burn in it afterwards, “ which is precisely the effect of all phlogistic processes, I now conclude that the “ maxim, suggested in this paragraph, is “ universally true.”

This hypothesis seems very ingenious and probable; and, till any other more plausible

plausible be offered, or experiments contradict it, I think we may safely make use of it in pursuing our electrical investigations, and endeavour to reconcile to it the phenomena already discovered in Electricity.

C H A P. IV.

Of the Place occupied by the electric Fluid.

BEFORE we quit the hypothetical part of this Treatise, it may be proper to say something concerning the residence of the electric fluid, either natural to a body, or superinduced on it. That the electric fluid, proper to a body when in its natural state, is equally diffused throughout all its substance, I think no one will deny; because that fluid is attractive of the particles of all other matter, and the particles of other matter are attractive of the electric fluid; and as this attraction is in proportion to the quantity of homogeneous matter, any quantity of matter will certainly attract a quantity of electric fluid proportionable to itself; therefore, the
electric

electric fluid must be equally diffused throughout all the parts of that portion of matter. This proposition, however, will take place only in speaking of Conductors; for it is founded upon the supposition, that the electric fluid, proper to a body in its natural state, does freely pervade that substance; but whether this is a fact respecting Electrics, or not, hath not hitherto been ascertained. As far as may be judged from experiments, I should suppose this rule to hold good with Electrics also; and my supposition is founded upon the following reasoning:—All the Electrics, when made very hot, become Conductors*; in that state, therefore, the above rule must hold good, *i. e.* the electric fluid, proper to their quantity of matter, must be equally diffused throughout their substance: and as all the Electrics in nature, before they became such (we may suppose) were Conductors; in that state they certainly had

* As this proposition has been found true in all the experiments hitherto made, I think it may be considered very properly, as a general law in the science of Electricity.

their proper share of fluid. Now as they afterwards cool, and become Electrics, it should seem that the change of their nature could not affect the equal diffusion of the electric fluid, which took place whilst they were in a conducting state. In consequence of this consideration, the difference between a Conductor and a Non-conductor, in regard to their natural quantity of electric fluid, is, that in the former, the fluid may easily move, whereas in the latter, it is confined in its pores. But it may be asked, whether a quantity of electric matter contains as much electric fluid as an equal quantity of conducting matter; a piece of rosin, for instance, when melted, does it contain more, less, or the same quantity, of electric fluid as when cold? To this question I can give no satisfactory answer; for, by the experiments hitherto made, nothing certain has been determined. Dr. PRIESTLEY, in order to ascertain this matter, made the following experiment:—He made a piece of glass red-hot (in which state it is a Conductor) and placing it upon an insulated piece of copper, left it in that situation till quite cold
(i. e.

(*i. e.* till it became an Electric); but in all the time of its cooling, no Electricity of any kind was perceived, either in the copper or glass; which would have certainly been the case, if the piece of glass had contained either more or less fluid when in an Electric, than when in a conducting state*. This experiment seems to give a decisive answer to the above question; but when the experiments, mentioned in the first part, of melting an electric substance into another, and other facts of a similar nature, are duly considered, they seem to make the answer again difficult §. It must therefore be confessed, that this matter remains as yet unsettled; and nothing but further experiments, and the discovery of other facts, can determine any thing satisfactory about it.

* History of Electricity, p. 716.—Experiments of a similar nature are met with in BECCARIA's *Electricismo Artificiale*.

§ The wax-chandlers, in forming their mafs into sticks, &c. find it so strongly attractive of dust, &c. that they are obliged to use great caution in keeping it at a sufficient distance from the charcoal fire, over which they work, lest it should (as sometimes happens) cover itself with ashes, and thus spoil the work.

In respect to the place occupied by the electric fluid superinduced on a body, it has been thought, by several ingenious persons, that, when a body is electrified, all the superfluous fluid, or all the deficiency of it, in case the body is electrified negatively, resides as a kind of atmosphere all around the body; to this atmosphere they attribute the phosphoreal smell, and that tickling sensation produced by an excited Electric; and they even suppose that these atmospheres may be made visible. But to this assertion it is answered by others, that if the Electricity communicated to a body did reside round it like an atmosphere, it should certainly repel the air contiguous to that body; but this is not the result of experiments; for it has been found that the electric atmosphere, however dense, if it does at all exist, has no effect upon the air contiguous to the electrified body, nor has the motion of the air, even a violent wind, any effect upon the atmosphere. In regard to the above-mentioned sensations of phosphoreal smell, &c. it is thought that they are only occasioned by the electric fluid

I entering

entering or going out of the skin in a very subdivided manner.

From what may be deduced from experiments, it appears that, although the electric fluid is transmitted through the substance of Conductors, yet no communicated Electricity can be observed within a sufficiently narrow cavity of an electrified body; besides, if two bodies of the same size and figure, but of different densities, are electrified together, and afterwards separated, they will acquire each the same quantity of Electricity, *i. e.* the Electricity that they acquire will be proportional to their surfaces, and not to their respective quantities of matter.

We may lastly conclude, that the Electricity communicated to a body, lies not diffused throughout the substance of that body, but on that surface of it which is contiguous to a free Electric, *i. e.* to an Electric, that is not surrounded by an homologous Electricity.

P A R T III.

PRACTICAL ELECTRICITY.

C H A P. I.

Of the electrical Apparatus in general.

HITHERTO we have treated of Electricity only theoretically, having noted what has been found uniformly certain relative to this subject, and having exhibited a view of the most probable conjectures offered in explanation of electrical appearances; but Electricity being a science, that requires a more practical management, than perhaps any other branch of natural philosophy, it is necessary, that we should now treat of it practically, and give the best directions we are able, both in regard to the construction of the necessary apparatus, and to the performance of the experiments, not only requisite in proving the foregoing Propositions,

tions, but such also as are pleasing and entertaining.

In this part of my work the reader will perhaps find more novelty, than he expects; for, considering the number of books that have been lately published on this subject, one would imagine that all the experiments possible to be exhibited with an electrical machine, and its appendages, have already been described. The case however is much the contrary; for not only the old experiments have been diversified, but a variety of new ones have been invented, and even the principal part of the apparatus has undergone several changes, and improvements.

In order the more regularly to proceed in the description of the electrical apparatus, it will not be improper to divide its parts into three classes; considering in the first, the instruments necessary to produce Electricity; in the second, those proper to accumulate, retain, and employ it; and lastly, those necessary to measure its quantity, and ascertain its quality.

The principal instrument to produce Electricity, is the electrical Machine, *i. e.* a machine capable by any means of exciting an Electric, so as to produce electrical appearances. The construction of those machines, from their first invention to the present time, has undergone so many changes, and their forms have been so much varied, that it would be very difficult, and even tedious, to describe those only which are most frequently in use. Every maker, and almost every Electrician constructs his own machines in a manner different from the rest; and, as new facts, or long practice points out some imperfections, the Electrician is ready to contrive a new method to correct the preceding errors. Indeed the rapid advance of the science is mostly owing to this change, and variety of constructions; for whether casual, or designed, a new construction has generally either produced some discovery of importance, or exposed some defect in the apparatus, and management of the same.

That the reader may be left at the liberty of choosing the form of his machine,

chine, I shall in this chapter lay down the most necessary rules to construct electrical machines in general; and shall reserve for the next chapter the particular description of some machines, that are the most useful, and which contain all the improvements hitherto made.

The principal parts of the machine are the Electric, the moving Engine, the Rubber, and the prime Conductor, *i. e.* an insulated Conductor, which immediately receives the Electricity from the excited Electric.

The Electric was formerly used of different substances, as glass, rosin, sulphur, sealing-wax, &c.; and of different forms, as cylinders, globes, spheroids, &c. This diversity then obtained on two accounts, first, because it was not ascertained, which substance or form would answer best, and secondly, on account of producing a negative, or positive Electricity, at the pleasure of the operator; for before the Electricity of the insulated rubber was discovered, sulphur, rough glass, or sealing-wax, was

generally used for the negative Electricity. At present, smooth glass only is used ; for when the machine has an insulated rubber, the operator may produce positive or negative Electricity at his pleasure, without changing the Electric. In regard to the form of the glass, those commonly used at present are globes, and cylinders. The most convenient size for a globe, is from nine to twelve inches diameter: they are made with one neck, which is cemented * to a strong brass cap, in order to adapt them to a proper frame. The cylinders are made with two necks ; they are used to the greatest advantage without any axis, and their common size is from four inches diameter and eight inches long, to twelve inches diameter and two feet

* The best cement for electrical purposes is made with two parts of rosin, two of bees-wax, and one of the powder of red okre. These ingredients are melted, and mixed together in any vessel over the fire ; and afterwards kept for use. This kind of cement sticks very fast, and is much preferable to rosin only, as it is not so brittle, and at the same time insulates equally well.

long,

long; some have been made in London even of twenty-one inches in diameter. The glass generally used is the best flint, though it is not yet absolutely determined, which kind of metal is the best for electrical globes, or cylinders. The thickness of the glass seems immaterial, but perhaps the thinnest is preferable. It has often happened, that glass globes, and cylinders, in the act of whirling, have burst in innumerable pieces, with great violence, and with some danger to the by-standers. Those accidents are supposed to happen when the globes, or cylinders, after being blown, are suddenly cooled. It will therefore be necessary to enjoin the workman to let them pass gradually, from the heat of the glass-house, to the atmospherical temperature.

It has been long questioned whether a coating of some electric substance, as rosin, turpentine, &c. on the inside surface of the glass, has any effect to increase its electrical power; but now it seems pretty well determined, that if it does not increase the power of a good glass globe or cylinder, at least

least it does considerably improve a bad one. I have several times put a coating of rosin on the inside surface of phials and tubes, and have constantly found, that the worst of them received some improvement by it.

The most approved composition for lining glass globes, or cylinders, is made with four parts of Venice turpentine, one part of rosin, and one part of bees-wax. This composition must be boiled for about two hours over a gentle fire, and must be kept stirring very often: afterwards it is left to cool, and reserved for use. When a globe or cylinder is to be lined with this mixture, a sufficient quantity of it is to be broken into small pieces, and introduced into the glass; then, by holding the glass near the fire, the mixture is melted, and equally spread over all its internal surface, to about the thickness of a sixpence. In this operation care must be taken, that the glass be made hot gradually, and be continually turned, so as to be heated equally in all parts, otherwise, it is apt to break in the operation.

In

In respect to the Engine which is to give motion to the Electric, multiplying wheels have been generally used; which, properly adapted, might give the Electric a quick motion, while they are conveniently turned by a winch. The usual method is, to fix a wheel on one side of the frame of the machine, which is turned by a winch, and has a groove round its circumference. Upon the brass cap of the neck of the glass globe, or one of the necks of the cylinder, a pulley is fixed, whose diameter is about the third or fourth part of the diameter of the wheel; then a string or strap is put over the wheel and the pulley, and by these means, when the winch is turned, the globe or cylinder makes three or four revolutions, for one revolution of the wheel. There is an inconvenience generally attending this construction, which is, that the string is sometimes so very slack, that the machine cannot work. To remedy this inconvenience, the wheel should be made moveable with respect to the Electric, so that by means of a screw it might be fixed at the proper distance; or else the pulley

pulley should have several grooves of different radiuses on its circumference.

It has been customary with some, to turn the cylinder simply with a winch, without any accelerated motion; but that seems not sufficient to produce the greatest electric power, the glass is capable of giving; for the globe or cylinder should properly make about six revolutions in a second, which is more than can be conveniently done with the winch only. This method however, on account of its simplicity, and easy construction, should not be disregarded, and it may be conveniently used, when no very great power is required.

Instead of the pulley and the string, as above described, a wheel and pinion, or a wheel, and an endless skrew, has been also used. This construction answers perhaps as well as any other; but, it must be constructed with great nicety, otherwise, it is apt to make a disagreeable rattling, and without frequent oiling, soon wears away by the great friction of its own parts.

The

The next thing belonging to the Electrical machine, necessary to be described, is the rubber, which is to excite the Electric. The rubber, as it is now made, is nothing more than a silk cushion stuffed with hair; and over this cushion is put a piece of leather, on which some amalgam * has been rubbed, so as to stick as fast as possible to the leather. Some time ago it was generally used, and it is now customary also, to make the rubber of red basil skin stuffed with hair; but the silk one, as above described (which is an improvement of Dr. NOOTH) is much preferable. If this silk cushion, on account of adapting it to the surface of the glass, is to be fixed upon a metal plate, then care should be taken to make the plate free from sharp points, edges, or corners, and it should be as much as possible concealed, or covered

* The amalgam has been found to excite smooth glass most powerfully. Any metal, dissolved in quick-silver, will perhaps do equally well, but the amalgam that has been generally used, is made with two parts of quick-silver and one of tin-foil, with a small quantity of powdered chalk, mixed together until it becomes a mass, like paste. An amalgam made with one part of zinc, and four or five parts of mercury, answers still better, as discovered by Dr. HIGGINS. *Mosaic gold* may also be used,

with

with silk. In short, to construct the rubber properly, it must be made in such a manner, that the side of it, which the surface of the glass enters in whirling, may be as perfect a Conductor, as it can be made, in order to supply Electricity as quick as possible; and the opposite part should be as much a Non-conductor as possible, in order that none of the fluid accumulated upon the glass, may return back to the rubber, which has been found by experiment to be the case, when the rubber is not made in a proper manner. For which reason a piece of silk is also added to the extremity of the leather.

The rubber should be supported by a spring, by which means it may easily suit any inequalities that may be found on the surface of the glass; and by a skrew it may be made to press harder or softer, as occasion may require. It should also be insulated in whatever manner is most convenient; for whenever insulation is not required, a chain or wire, &c. may be occasionally hung upon it, and thus communicate with the earth, or with any other body, at pleasure; whereas, when there is not a contrivance for insulating the rubber, many of the most curious experiments

experiments in Electricity will never be performed with the machine.

We come now to consider the prime Conductor, or first Conductor, which is nothing more than an insulated conducting substance furnished with one or more points at one end, in order to collect the Electricity immediately from the Electric. When the Conductor is of a moderate size, it is usual to make it of hollow brass, but when it is very large, then, on account of the price of the materials, it is made of paste-board, covered with tin-foil, or gilt paper. The Conductor is generally made cylindrical; but let the form be what it will, it should always be made perfectly free from points, or sharp edges; and if holes are to be made in it, which on many accounts are very convenient, they should be well rounded, and made perfectly smooth. Further, that end of the prime Conductor, which is at the greatest distance from the Electric, ought to be made larger than the rest, as the strongest exertion of the electric fluid, in escaping from the Conductor, is always at that end.

It has been constantly observed, that the
larger

larger the prime Conductor is, the longer, and denser spark can be drawn from it; and the reason of this is, that the quantity of Electricity, discharged in a spark, is nearly proportional to the size of the Conductor; on this account the prime Conductor is now made much larger, than what was formerly used. Its size, however, may be so large, that the dissipation of the Electricity from its surface, may be greater than what the Electric can supply; in which case so large a Conductor would be nothing more than an unwieldy, and disagreeable incumbrance.

Before we quit the Electrical machine, it should be observed, that, besides the above-mentioned parts, it is necessary to have a strong frame to support the Electric, the rubber, and the wheel. The prime Conductor should be supported by stands with pillars of glass, or baked wood, and not by silk strings, which admit of continual motion. In short, the machine, the prime Conductor, and any other apparatus actually used, should be made to stand as steady as possible, otherwise many inconveniences will arise.

Besides

Besides the Electrical machine, the Electrician should be provided with glass tubes of different sizes, a pretty large stick of sealing-wax, or a glass tube covered with sealing-wax, for the negative Electricity. He should at least not be without a glass tube about three feet long, and one inch and a half in diameter. This tube should be closed at one end, and at the other end should have fixed a brass cap with a stop-cock, which is useful in case it should be required to condense, or rarefy the air within the tube.

The best rubber for a tube of smooth glass is the rough side of black oiled silk, especially when it has some amalgam rubbed upon it; but the best rubber for a rough glass tube, a stick of baked wood, sealing-wax, or sulphur, is soft new flannel.

The instruments necessary for the accumulation of Electricity, are coated Electrics, among which, glass coated with Conductors obtains the principal place; on account of its strength it may be formed into any shape, and it will receive a very great charge. The form of the glass is immaterial with respect

to the charge it will contain ; its thickness only is to be considered, for the thinner it is, the higher charge it is capable of receiving ; but it is at the same time more subject to be broken by the force of electric attraction ; for this reason, therefore, a thin coated jar, or plate may be used very well by itself, and it is very convenient for many experiments ; but when large batteries are to be constructed, then it is necessary to use glass a little thicker, and care should be taken to have them perfectly well annealed. If a battery is required of no very great power, as containing about eight or nine square feet of coated glass, I should recommend to make use of common pint, or half-pint phials, such as apothecaries use. They may be easily coated with tin-foil, sheet-lead, or gilt-paper on the outside, and brass-filings on the inside ; they occupy a small space, and, on account of their thinness, hold a very good charge. But when a large battery is required, then these phials cannot be used, for they break very easily ; and for that purpose cylindrical glass jars, of about fifteen inches high, and four or five inches in diameter, are the most convenient. One large jar

jar answers better than several small ones, because the dissipation of the electric fluid over the uncoated part is not so considerable in the former as in the latter case. But then, if a large jar breaks, the loss is much more considerable.

When glass plates or jars, having a sufficiently large opening, are to be coated, the best method is to coat them with tin-foil on both sides, which may be fixed upon the glass with varnish, gum-water, bees-wax, &c.; but in case the jars have not an aperture large enough to admit the tin-foil, and an instrument to adapt it to the surface of the glass, then, brass filings, such as are sold by the pin-makers, may be advantageously used, and they may be stuck with gum-water, bees-wax, &c. but not with varnish, for this is apt to be set on fire by the discharge, as will appear in the latter part of this work. Care must be taken that the coatings do not come very near the mouth of the jar, for that will cause the jar to discharge itself. If the coating is about two inches below the top, it will in general do very well; but there are some kinds of glass, especially

tinged glass, that, when coated and charged, have the property of discharging themselves more easily than others, even when the coating is five or six inches below the edge *. There is another sort of glass, like that of which Florence flasks are made, which, on account of some unvitriified particles in its substance, is not capable of holding the least charge; on these accounts, therefore, whenever a great number of jars are to be chosen for a large battery, it is adviseable to try some of them first, so that their quality, and power may be ascertained.

Electricians have often endeavoured to find some other Electric, which might answer better than glass for this purpose, at least be cheaper; but, except Father BECCARIA's method, which may be used very well, I do not find that any remarkable discovery has been made relating to this point.

Father BECCARIA took equal quantities of very pure colophonium, and powder of

* When a jar discharges itself, the electric fluid runs from the inside to the outside coating over the surface of the glass, where it leaves an indelible mark all along its path, which is mostly in a zig-zag form.

marble sifted exceedingly fine, and kept them in a hot place for a considerable time, where they became perfectly free from moisture; he then mixed them, and melted the composition in a proper vessel over the fire, and when melted poured it upon a table, upon which he had previously stuck a piece of tin-foil, reaching within two or three inches of the edge of the table; this done, he endeavoured with a hot iron to spread the mixture all over the table as equally as possible, and to the thickness of one tenth of an inch; he afterwards coated it with another piece of tin-foil reaching within about two inches of the edge of the mixture; in short, he coated a plate of this mixture like a plate of glass. This coated plate, from what he says, seems to have had a greater power than a glass plate of the same dimensions, even when the weather was not very dry: and, if it is not subject to break very easily by a spontaneous discharge, I think it may be very conveniently used; for it doth not very readily attract moisture, and consequently may hold a charge of Electricity better, and longer than glass: besides, if broken, it may be repaired by a hot iron;

but glass, when broke, can never be repaired.

When a jar, a battery, or in general, a coated Electric, is to be discharged, the operator should be provided with an instrument called the discharging Rod, which consists of a metal rod sometimes straight, but more commonly bended in the form of a C: they are made also of two joints, so as to open like a kind of compasses. This rod is furnished with metal knobs at its extremities, and has a non-conducting handle, generally of glass or baked wood, fastened to its middle. When the operator is to use this instrument, he holds it by the handle, and, touching one of the coated sides of the charged Electric with one knob, and approaching the other knob to the other coated side, or some conducting substance communicating with it, he completes the communication between the two sides, and discharges the Electric.

The instruments to measure the quantity, and ascertain the quality of Electricity, are commonly called *Electrometers*; and they are of four sorts, 1st. the single Thread, 2d. the

Cork, or Pith-balls, 3d. the Quadrant, and 4th. the discharging Electrometer *. But a particular description of the same will be found in the third chapter of this work.

Besides the apparatus above described, there are several other instruments useful for various experiments, but these will be described occasionally. The Electrician, however, ought to have by him not only a single coated jar, a single discharging rod, or in short, only what is necessary to perform the common experiments; but he should provide himself with several plates of glass, with jars of different sizes, with a variety of different instruments of every kind, and even tools for constructing them; in order that he may readily make such new experiments, as his curiosity may induce him to try, or that may be published by other ingenious persons, who are pursuing their researches in this branch of philosophy.

* The second sort of Electrometer, *i. e.* the cork-balls Electrometer, was invented by Mr. CANTON: the discharging Electrometer was invented by Mr. LANE, and another, on a different principle, by Mr. RINNER-SLEY: and the quadrant Electrometer, which is of latest invention, is a contrivance of Mr. HENLY.

C H A P. II.

*The description of some particular electrical
Machines.*

IN this chapter I shall present the reader with the particular description of three electrical machines, which, I think, will be very acceptable after the general account of their construction, which has already been given. The first of these is that described by Dr. PRIESTLEY, in his History of Electricity *; where a drawing of the same may be seen, and which, on account of its extensive use, may be deservedly called a universal electrical Machine.

The basis of this machine consists of two oblong boards, which are kept in a situation parallel to one another, about four inches asunder, by two small pieces of board properly adapted to that purpose. These boards, when set horizontally upon a table, and there fixed by fastening the lower of them with iron cranks, form the support of two perpendicular pillars of

* Part V. sec. II.

baked wood, and of the rubber of the machine. One of the pillars, together with the spring supporting the rubber, slides in a groove, which reaches almost the whole length of the upper board, and, by means of screws, may be placed at any required distance from the other pillar, which is fixed, being let through a mortice in the upper board, and strongly fastened to the lower. In these two pillars are several holes for the admittance of the spindles of different globes, and, as they may be situated at any distance from one another, they may be adapted to receive not only globes, but also cylinders, or spheroids of different sizes. In this machine, says Dr. PRIESTLEY, more than one globe or cylinder may be used at once, by fixing them one above the other in the different holes of the pillars; and by adapting to each a proper pulley, they may be whirled all at once, and their power united, in order to increase the Electricity *; but in this construction I do
not

* When several globes are used at once, and their power is united, it has been found by experiment, that the Electricity does not increase in proportion to their
number,

not think that different rubbers can be conveniently applied to them all; which is a capital imperfection.

“ The rubber consists of a hollow piece
 “ of copper, filled with horse-hair, and
 “ covered with a basil skin. It is sup-
 “ ported by a socket, which receives the
 “ cylindrical axis of a round and flat piece
 “ of baked wood, the opposite part of
 “ which is inserted into the socket of a
 “ bent steel spring. These parts are easily
 “ separated, so that the rubber, or the piece
 “ of wood that serves to insulate it, may
 “ be changed at pleasure. The spring
 “ admits of a two-fold alteration of posi-
 “ tion. It may be either slipped along the
 “ groove, or moved in the contrary direc-
 “ tion” (the groove being wider than
 the screw which fastens the spring), “ so
 “ as to give it every desirable position with

number, although it is more, than what may be produced by a single globe. However, as the friction, and the difficulty of working the machine, increases in proportion to the number of globes or cylinders, so I think that one good large cylinder is preferable to many of them.

“ respect

“ respect to the globe or cylinder ; and it
“ is, besides, furnished with a screw,
“ which makes it press harder or lighter,
“ as the operator chooses.”

The wheel of this machine is fixed to the table ; it has several grooves, for admitting more strings than one, in case that two or three globes, or cylinders are used at a time ; and as it is disengaged from the frame of the machine, the latter may be skrewed at different distances from the former, and thus suited to the variable length of the string.

The prime Conductor is of hollow copper, made in the shape of a pear, situated with its neck upwards, and with its bottom or rounder part upon a stand of baked wood ; and an arched wire proceeds from its neck, having an open ring at its end, in which some small pointed wires are hung, that by playing lightly upon the Electric collect the electric fluid from it. This form of prime conductor is, however, very improper.

This

This machine, notwithstanding that it has several imperfections, is yet a very good contrivance; but, except different globes, or cylinders, or several of those at once, are required to be used, I think a great deal of the work may be spared, and the machine might be made more simple, and concise.

Next to Dr. PRIESTLEY's machine, I shall describe another, which, for its simplicity, and conciseness, makes a fine contrast with the former.

This machine consists of a circular glass plate, about one foot diameter, which is turned vertically by a winch fixed to the iron axis that passes through its middle; and it is rubbed by four cushions, each about two inches long, situated at the opposite ends of the vertical diameter.

The frame consists of a bottom board, about a foot square, or a foot long and six inches broad, which, when the machine is to be used, may be fastened by an iron crank to the table. Upon this board two other slender, and smaller ones are raised, which

which lie parallel to one another, and are fastened together at their top by a small piece of wood. These upright boards support in their middle the axis of the plate, and to them the rubbers are fastened.

The Conductor is of hollow brass, and from its extremities branches are extended, which coming very near the extremity of the glass, collect the Electricity from it.

The power of this machine is perhaps more than a person would judge by looking at it. It may be objected, that this construction will not easily admit of the rubbers being insulated, nor consequently be adapted to a great variety of experiments; but at the same time it must be allowed, that it is very portable, that it is not very liable to be out of order, and that it has a power sufficiently strong for several purposes; on which account it may be conveniently used. These machines have often been made with two parallel glass plates, and those of a considerable diameter; which plates, turning upon the same axis,

axis, are rubbed by eight rubbers.—The sparks obtained from the conductors of those machines are strong, though not very long; yet an electrical battery may be charged by one of those machines very quick, since they accumulate an astonishing quantity of electric fluid. Their principal imperfections are—the great number of rubbers that the operator must keep in proper order—the friction arising from them, which renders the turning of the machine rather hard—and lastly, the plates being subject to crack very easily.

The last machine, that I am to describe, is that represented in fig. 1 of plate I, which has all the improvements hitherto made, except that it is not capable of admitting different kinds, or more than one Electric, but which, indeed, it seems not to stand in need of. The electric power of such a machine, I think, is equal to what may be obtained by any other construction; and at the same time its size, being neither remarkably large, nor at all inconvenient, renders

renders it, I think, the *completest machine* hitherto contrived*.

The frame of this machine consists of the bottom board A B C, which, when the machine is to be used, is fastened to the table by two iron cranks, one of which appears in the figure near C. Upon the bottom board are perpendicularly raised two strong wooden pillars K L, and A H, which support the cylinder, and the wheel. From one of the brass caps of the cylinder F F, an axle of steel proceeds, which passes quite through a hole in the pillar K L, and has on this side of the pillar a pulley I, fixed upon its square extremity. Upon the circumference of this pulley there are three or four grooves, in order to suit the variable length of the string *a b*, which goes round one of them, and round the groove of the wheel D. The other cap of the cylinder has a small cavity, which fits the conical extremity of a strong skrew, that proceeds from the pillar H. The

* These machines are made, and sold, by Mr. GEORGE ADAMS, in Fleet-street, London, philosophical instrument-maker to his Majesty.

wheel D, which is moved by the handle E, turns round a strong axle, proceeding from almost the middle of the pillar K L.

The rubber G of this machine is on each end three or four inches shorter than the cylinder (*i. e.* the cylinder exclusive of the necks), and it is made to rub about one fifth part of the cylinder's circumference, or rather less; it consists of a thin quilted cushion of silk, stuffed with hair, and fastened by silk strings upon a piece of wood, which is properly adapted to the surface of the cylinder. And to the lower extremity of the cushion, or rather of the piece of wood to which the cushion is tied, a piece of leather is fastened, which is turned over the cushion, *i. e.* stands between it and the surface of the cylinder, and to the extremity of which a piece of silk or oiled silk is fastened, which covers almost all the upper part of the cylinder. Upon this leather, which reaches from the lower to almost the upper extremity of the cushion, some of the above-described amalgam is to be worked, so as to be forced as much as possible into its substance: if mosaic gold is

is to be tried, then the leather should be new, and whereon no other amalgam has been put. This rubber is supported by two springs, screwed to its back, and from which it may be easily unscrewed, when occasion requires it. The two springs proceed from the wooden cap of a strong glass pillar *, perpendicular to the bottom board of the machine. This pillar has a square wooden basis, that slides in two grooves in the bottom board A B C, upon which it is fastened by a screw. In this manner the glass pillar may be fastened at any required distance, and in consequence the rubber may be made to press harder or lighter upon the cylinder. The rubber in this manner is perfectly insulated; and, when insulation is not required, a chain with a small hook

* This glass pillar, as well as the glass feet of insulating stools in general, should be covered with varnish, or rather with sealing-wax, otherwise they insulate very imperfectly, on account of the moisture that they attract from the air, especially in damp weather. It must be observed, that sealing-wax dissolved in spirits of wine, may be used very well for this purpose; but to cover a piece of glass with sealing-wax, by rubbing a stick of it upon the surface of the glass when hot, answers far the better.

M

may

may be hanged to it, so as to have a regular communication with the piece of leather, the chain then falling upon the table, renders the rubber uninfulated.

Fig. 2 represents the prime Conductor AB belonging to this machine. This is of hollow brass, and is supported by two glass pillars varnished, that by two brass sockets are fixed in the board CC. This Conductor receives the electric fluid through the points of the collector L, which are set at about half an inch distance from the surface of the cylinder of the machine.

If the handle E, fig. 1, of the wheel, be turned (and on account of the rubber it should be turned always in the direction of the letters *a b c*) this machine, standing in the situation that is represented in the figure, will give positive Electricity, *i. e.* the prime Conductor will be electrified positively, or overcharged with electric fluid; for by the action of rubbing, the cylinder pumps, as it were, the fluid from the rubber, and every other body properly connected

connected with it, and gives it to the prime Conductor. But if a negative Electricity is required, then the chain must be removed from the rubber and hung to the prime Conductor; for in this case the Electricity of the prime Conductor will be communicated to the ground, and the rubber remaining insulated, will appear strongly negative. Another Conductor, equal to the Conductor A B, fig. 2, may be connected with the insulated rubber, and then the operator may obtain as strong negative Electricity from this, as he can positive from the Conductor A B, fig. 2.

C H A P. III.

The particular Description of some other necessary Parts of the electrical Apparatus.

FIG. 4 represents a stand supporting the electrometers D D C C. B is the basis of it, made of common wood. A is a pillar of wax, glass, or baked wood. To the top of the pillar, if it be of wax or glass, a circular piece of wood is fixed; but

if the pillar be of baked wood, that may constitute the whole. From this circular piece of wood proceed four arms of glass, or baked wood, suspending at their ends four electrometers, two of which, *DD*, are silk threads about eight inches long, suspending each a small downy feather at its end. The other two electrometers, *CC*, are those with very small balls of cork, or of the pith of elder; and they are constructed in the following manner:—*ab* is a stick of glass about six inches long, covered with sealing-wax, and shaped at top in a ring: from the lower extremity of this stick of glass proceed two fine linen threads* *cc*, about five inches long, each suspending a cork, or pith-ball *d*, about one-eighth of an inch in diameter. When this electrometer is not electrified, the threads *cc* hang parallel to each other, and the cork-balls are in contact; but when electrified, they repel one another, as represented in the figure. The glass stick *a b* serves for an insulating handle, by which the electrometer may be

* These threads should be wetted in a weak solution of salt:

supported,

supported, when it is used without the stand A B.

Another species of the above electrometer is represented in fig. 3; which consists of a linen thread, having at each end a small cork-ball. This electrometer is suspended by the middle of the thread on any Conductor proper for the purpose, and serves to shew the kind, and quantity of its Electricity.

Fig. 7 represents Mr. HENLY's quadrant electrometer, fixed upon a small stand, from which it may be occasionally separated, and fixed upon the prime Conductor, or in any other place at pleasure. This electrometer consists of a perpendicular stem, formed at the top like a ball, and furnished at its lower end with a brass ferrule, by which it may be fixed in one of the holes of the prime Conductor, or in its proper stand, as occasion requires. To the upper part of the stem, or pillar, a graduated ivory semicircle is fixed, about the middle of which is a brass arm, which contains a pin, or the small axis of the index. The index

consists of a very slender stick, which reaches from the center of the graduated semicircle to the brass ferrule, and at its lower extremity is fastened a small cork-ball, nicely turned in a lathe.

The properest wood, for the purpose of making the pillar and index of this electrometer, is box, and this pillar and index should be well rounded, and made as smooth as possible. When this electrometer is not electrified, the index hangs parallel to the pillar, as in fig. 7; but when it is electrified, the index recedes more or less, according to the quantity of Electricity, from the stem; as represented on the prime Conductor E, fig. 2.

The main of Mr. LANE's discharging Electrometer, consists in a brass ball about one inch and a half in diameter, screwed to a brass graduated rod, and adapted to a proper frame, so that it may be set at any required distance from the prime Conductor, or the knob of an electric jar. The principal use of this electrometer is to let a jar
discharge

discharge by itself through any proper circuit, without using any discharging rod, or removing any part of the apparatus; and to give shocks nearly of the same strength. Suppose, for instance, that the above-mentioned brass ball be set at half an inch distance from the prime Conductor, and that a coated jar be situated so as to touch the prime Conductor with its knob, and to have its outside coating communicating with the above-mentioned brass ball. Now it is evident that the circuit, from the outside to the inside of the jar, is interrupted only between the prime Conductor and the brass ball, which lie half an inch asunder; therefore, when the jar is charging, and the charge is become so high as to strike through half an inch of air, the jar will discharge itself, and, by keeping the brass ball at the same distance from the prime Conductor, and charging the jar successively, the shocks will be of the same strength.

This electrometer is subject to an inconvenience; which is, that the surface of the brass ball is sometimes deprived of its

smoothness by the force of the explosion; in which case it is necessary to polish it again, otherwise the instrument is useless. An electrometer of this kind, though not exactly like the original one, is now commonly used by the practitioners of medical electricity, and is delineated in fig. 6. of Plate II. It consists of a glass arm D, which proceeds from the wire of the jar F, and to the extremity E of which a spring socket is cemented, through which a wire passes, which is furnished with a knob B, towards the knob A of the jar, and of an open ring C at its other extremity. Now, as this wire may be slid backwards and forwards, the knob B may be put at any required distance from the knob A, as far as the construction of the instrument will allow. The wire BC is generally marked with divisions, which shew the distance of the two knobs, when the wire is so situated, as that the required division coincides with the edge of the spring socket, as for instance, one tenth, or one quarter of an inch, &c. When the jar F is set against the prime conductor G, as represented in the figure, suppose that the ball B

is set at the distance of $\frac{1}{10}$ of an inch from the ball A, and that a wire be fixed from the electrometer's ring to the outside coating of the jar, as shewn by the dotted line CK; then, when the machine is put in motion, the discharge of the jar, as soon as this becomes sufficiently charged, will be made between the knobs AB, and through the wire CK; and it is evident that these discharges will be of the same strength, as long as the distance between AB remains the same.

Fig. 5 of Plate I. represents Mr. HENLY's universal discharger, which is of a very extensive use, and is composed of the following parts:—A is a flat board fifteen inches long, four inches broad, and one thick, or thereabouts, which forms the basis of the instrument. BB are two glass pillars, cemented in two holes upon the board A, and furnished at their top with brass caps, each of which has a turning joint, and supports a spring tube, through which the wire DC slides: each of these caps is composed of three pieces of brass, connected so, that the wire DC, besides its sliding through the socket, has two other motions,
viz,

viz. an horizontal and a vertical one. Each of the wires DC, DC is furnished with an open ring at one end, and at the other end has a brass ball D, which, by a short spring socket, is slipt upon its pointed extremity, and may be removed from it at pleasure. E is a strong circular piece of wood, five inches in diameter, having, on its surface, a slip of ivory inlaid, and furnished with a strong cylindrical foot, which fits the cavity of the socket F, which is fastened in the middle of the bottom board, and has a screw G, which serves to fasten the foot of the circular board E at any required height. H is a small press belonging to this instrument; it consists of two oblong pieces of board, which may be pressed against each other by means of two screws *a a*: the lower of these boards has a cylindrical foot equal to the foot of the circular board E. When this press is to be used, it is fixed into the socket F, in the place of the circular board E, which must, in that case, be removed.

Fig. 11 is an electric jar coated with tin-foil on the inside and outside, within

three inches of the top of the cylindrical part of the glass, having a wire with a round brass knob A at its extremity. This wire passes through the cork * D, that stops the mouth of the jar, and at its lower end, is bended so as to touch the inside coating in several places.

Fig. 10 represents a battery composed of sixteen jars, coated in the inside and outside with tin-foil, which all together contain about twelve feet of coated glass. About the middle of each of these jars is a cork that sustains a wire, which at the top is fastened round, or soldered to the wire E, knobbed at each end, which connects the inside coatings of four jars; and by the wires F F F the inside coatings of all the sixteen jars are connected together. Each of the wires F has a ring at one end, through which one of the wires E passes, and at the other end has a brass knob. If the whole force of the battery is not required, one, two, or three rows of jars may be used

* When corks are used to stop electric jars, they should be made very dry, and dipped in melted beeswax, or varnished.

at pleasure; for as each of the wires F F F is moveable round the wire E, which passes through its ring, and rests upon the next wire E, it may be easily removed from that, and turned upon the contrary wire E; and thus the communication between one row of jars and another may be discontinued at pleasure. See the figure.

The square box that contains these jars is of wood lined at the bottom with sheet-lead or tin, and has two handles on two opposite sides, by which it may be easily removed. In one side of the box is a hole, through which an iron hook B passes, which communicates with the metallic lining of the box, and consequently with the outside coating of all the jars. To this hook is fastened a wire, the other end of which is connected with the discharging-rod.

The discharging-rod consists of a glass handle A, and two curved wires B B, which move by a joint C, fixed to the brass cap of the glass handle A. The wires B B are pointed, and the points enter the knobs
D D,

DD, to which they are screwed, and may be unscrewed from them at pleasure. By this construction we have the opportunity of using the balls or the points, as occasion requires; and as the wires are moveable by the joint C, they may be adapted to smaller or larger jars at pleasure.

The battery, represented in the plate, is a small one in comparison to those now frequently used, and much too weak for the purpose of some experiments, hereafter to be described. But I thought it sufficient to give an idea of its construction; and, when a large battery is to be constructed, I would recommend rather to make two, three, or more small ones, as represented in the plate, than a single large battery, which is heavy, and, on several accounts, inconvenient. The force of several small batteries may be easily united by a wire or a chain, and thus they may be made to act like a large one.

F in fig. 2. is a circular brass plate hung on the prime Conductor by a chain, and resting in an horizontal position. Underneath

neath this, there is another plate P parallel, and equal to the former (but it would be better if it was a little larger), which is supported by a stand H of brass, having also a socket to receive the foot of the plate, and a screw G to fix it at different distances.

D in fig. 2. is a fly made of small brass wires, fixed in a cap of brass also; which is to be put upon the pointed wire K, that is screwed to the prime conductor, upon which it must stand in equilibrio, like the needle of a compass. The other ends *a*, *b*, *c*, *d* of the wires are pointed, and bent all one way.

N. B. Whenever hereafter I mention the prime Conductor, I mean the prime Conductor naked, that is, without the parallel brass plates F P, without the fly D and its supporting pin K, without the electrometers E, and even without the knobbed rod I B, which is screwed to it occasionally; except the contrary is expressed.

It is highly requisite for an Electrician to have by him several insulating stools, or
stands,

stands, they being very necessary for several experiments. The best materials to construct these are glass covered with sealing-wax, and baked wood*. A large stool, proper to insulate a chair upon, or two or three persons standing, may be made with a strong board, about two feet and a half square, and may be supported by four feet of glass, about eight inches long. But small stands are better made with one foot or pillar, and all of baked wood or glass, without any conducting substance in their construction. Drinking-glasses, either varnished, or in part covered with sealing-wax, answer this purpose very well.

* The wood should be baked very well, even till it becomes quite brown, it then being in the best state for insulation; and to make it still better, *i. e.* to defend it from moisture, it may be slightly varnished as soon as it comes out of the oven, or else boiled in linseed-oil; but in this case, after boiling, it should be made hot again, and then it is fit for use.

C H A P. IV.

Practical Rules concerning the Use of the electrical Apparatus, and the performing of Experiments.

IT often happens that young Electricians are at a loss to assign the reason, why some experiments do not succeed with them as described in the Treatises on Electricity. Sometimes they are in possession of very good instruments, but, by reason of some circumstance or other unattended to, they are quite useless in their hands. This indeed can be remedied by nothing but practice, and it is by long use, that the Electrician, as well as the Practitioner in any art or science, becomes so good an Operator, as to use his instruments to the best advantage. A few rules are however very necessary, to guide him in his operations; and although these alone are insufficient to make a person a complete practical Electrician, yet, when accompanied with the actual management of the apparatus, they facilitate

cilitate the use of it, and render the performance of the experiments more accurate and expeditious.

The first thing that the young Electrician should observe, is, the preservation, and care, of his instruments. The electrical machine, the coated jars, and in short every part of the electrical apparatus, should be kept clean, and as free as possible from dust, and moisture.

When the weather is clear, and the air dry, especially in clear and frosty weather, the electrical machine will always work well. But when the weather is very hot, the electrical machine is not so powerful: nor in damp weather, except it be brought into a warm room; and the cylinder, the stands, the jars, &c. be made thoroughly dry.

Before the machine be used, the cylinder should be first wiped very clean with a soft linen cloth, that is dry, clean, and warm; and afterwards with a clean hot flannel, or an old silk handkerchief; this done, if the

N

winch

winch be turned, when the prime Conductor, and other instruments, are removed from the electrical machine, and the knuckle be held at a little distance from the surface of the cylinder, it will be soon perceived that the electric fluid comes like a wind from the cylinder to the knuckle, and, if the motion be a little continued, sparks, and crackling will soon follow. This indicates that the machine is in good order, and the Electrician may proceed to perform his experiments. But if, when the winch is turned for some time, no wind is felt upon the knuckle, then the fault is, very likely, in the rubber; and to remedy that, use the following directions:—By unscrewing the screws on the back of the rubber, remove it from its glass pillar, and keep it a little near the fire, so that its silk part may be dried; take now a dry piece of mutton-suet, or a little tallow from a candle, and just pass it over the leather of the rubber, then spread a small quantity of the above-described amalgam over it, and force it as much as possible into the leather. This done, replace the rubber upon the glass pillar; let the glass cylinder be wiped

5

once

once more, and then the machine is fit for use.

Sometimes the machine will not work well, because the rubber is not sufficiently supplied with electric fluid; which happens when the table upon which the machine stands, and to which the chain of the rubber is connected, is very dry, and consequently in a bad conducting state. Even the floor and the walls of the room are, in very dry weather, bad Conductors, and they cannot supply the rubber sufficiently. In this case, the best expedient is, to connect the chain of the rubber, by means of a long wire, with some moist ground, a piece of water, or with the iron-work of the water pump; by which means the rubber will be supplied with as much electric fluid as is required.

It must be also remarked, that when the cylinder is very hot, as above 110° , it will not act well.

When a sufficient quantity of amalgam has been accumulated upon the leather of the rubber, and the machine does not work very well, then, instead of putting more

amalgam, it will be sufficient to take the rubber off, and to scrape a little, that which is already upon the leather.

It will be often observed, that the cylinder, after being used some time, contracts some black spots, occasioned by the amalgam, or some foulness of the rubber, which grow continually larger, and greatly obstruct its electric power. These spots must be carefully taken off, and the cylinder must be frequently wiped, in order to prevent its contracting them.

In charging electric jars in general, it must be observed, that not every machine will charge them equally high. That machine, whose electric power is the strongest, will always charge the jars highest. If the coated jars, before they are used, be made a little warm, they will receive, and hold the charge the better.

If several jars are connected together, among which there is one, that is apt to discharge itself very soon, then the other jars will also soon be discharged with that;
2 although

although they may be capable of holding a very great charge by themselves. When electric jars are to be discharged, the Electrician must be cautious lest, by some circumstance not adverted to, the shock should pass through any part of his body; for an unexpected shock, though not very strong, may occasion several disagreeable accidents. In making the discharge, care must be taken that the discharging-rod be not placed on the thinnest part of the glass, for that may cause the bursting of the jar.

When large batteries are discharged, jars will be often found broken in it, which burst at the time of the discharge. To remedy this inconvenience, Mr. NAIRNE says he has found a very effectual method; which is, never to discharge the battery through a good Conductor, except the circuit be at least five feet long, Mr. NAIRNE says, that ever since he made use of this precaution, he has discharged a very large battery near a hundred times, without ever breaking a single jar, whereas before he was continually breaking them. But here it must be con-

sidered, that the length of the circuit weakens the force of the shock proportionably; the highest degree of which is in many experiments required.

When a coated phial is cracked, either by a spontaneous discharge, or by any other accident, I remove the outside coating from the fractured part, and then make it moderately hot by holding it to the flame of a candle, and whilst it remains hot I apply burning sealing-wax to the part, so as to cover the fracture entirely; taking care that the thickness of the wax is rather more than the thickness of the glass. Lastly, I cover all the sealing-wax, and also part of the surface of the glass beyond it, with a composition made with four parts of bees-wax, one of resin, one of turpentine, and a very little oil of olives; which composition I spread upon a piece of oiled silk, and apply it in the manner of a plaister. With this method I have repaired several broken phials so effectually, that, after being frequently charged, they were at last broken
by

by a spontaneous discharge, but in a different part of the glass *.

It is adviseable, when a jar, and especially a battery, has been discharged, not to touch its wires with the hand, before the discharging-rod be applied to its sides a second, and even a third time; as there generally remains a residuum of the charge †, which is sometimes very considerable.

When any experiment is to be performed, which requires but a small part of the apparatus, the remaining part of it should be placed at a distance from the machine, the

* Here it is proper to remark, that when jars, or glass in general, that is coated for the purpose of charging and discharging, is in any manner covered with cement or sealing-wax, it breaks more easily by a spontaneous discharge; and it is very remarkable, that the fracture generally lies on the limits of the cement.

† This residuum is in great measure occasioned by the Electricity, that, when the jar is charging, spreads itself over the uncoated part of the glass near the coating, which will not be discharged at first, but gradually returns to the coating after the first discharge.

prime Conductor, and even from the table, if that is not very large. Candles, particularly, should be placed at a considerable distance from the prime Conductor, for the effluvia of their flames carry off much of the electric fluid,

Lastly, the young Electrician should be cautioned not to depend on first appearances in Electricity. A new phenomenon may justly excite his curiosity: it is laudable to remark it, and to pursue the hint; but at the same time even the doubtful assertion of a new fact should never be made, till after a number of similar and concurring experiments. Electricity is a science that often deceives the senses, and the most experienced Electrician frequently finds himself mistaken in things, which perhaps he may have before considered as the most certain.

CHAP. V.

*Experiments concerning electric Attraction,
and Repulsion.*

EXPERIMENT I.

The electrified Cork-ball Electrometer.

WHEN the electrical machine is put in order, and the prime Conductor it set so, that the points of the collector are about half an inch from the surface of the cylinder, fix at the end of the prime Conductor the knobbed rod I B fig. 2. and hang on it the electrometer with the cork-balls fig. 3. The balls will now touch one another, the threads hanging perpendicularly, and parallel to each other. But if the cylinder of the machine be whirled by turning the winch E, then the cork-balls will repel one another, and more, or less, according as the Electricity is more or less powerful.

In

In this experiment, the glass cylinder extracting the electric fluid from the rubber, throws it upon the pointed wires of the collector, and in consequence upon the prime Conductor, and the electrometer; which are all connected together: and as bodies overcharged with electric fluid will always repel each other, so the cork-balls must repel each other.

If the electrometer be hung to a prime Conductor negatively electrified, *i. e.* connected with the insulated rubber of the machine, the cork-balls will also repel each other; for bodies, undercharged, will repel each other, as well as bodies overcharged with electric fluid.

If, in this state of repulsion, the prime Conductor is touched with some conducting substance not insulated, the cork-balls will immediately come together; for the electric fluid superinduced upon the prime Conductor, and the electrometer communicating with it, will be carried away to the ground by that conducting body; so that in this case the prime Conductor can never be overcharged:

charged : nor can it be undercharged, if connected with the rubber; for its deficiency of fluid is supplied through that conducting body, with which it has been touched. But if, instead of the conducting substance, the prime Conductor is touched with an electric, as for instance a stick of sealing-wax, a piece of glass, &c. then the cork-balls will continue to repel each other; because the electric fluid cannot be conducted through that electric : hence we have an easy method of determining what bodies are Conductors, and what electrics *.

This electrical repulsion is also shewn by the quadrant electrometer, with a large downy feather, or the like ; for if these be connected with the prime Conductor, and the winch be turned, the electrometer will raise its index, and the feather, by the divergency of its down, will appear swelled in a beautiful manner.

* This method in gross will do very well ; but when the conducting power of fluids or some other bodies, and the degree of that power, is to be ascertained, then recourse must be had to other means more nice, and accurate.

EXPE-

EXPERIMENT II.

Attraction and Repulsion of light Bodies.

Connect with the prime Conductor the two parallel brass plates F, P, as represented in fig. 2. at about three inches distance from one another, and upon the lower plate put any kind of light bodies, as bran, bits of paper, bits of leaf-gold, &c. then work the machine, and the light bodies will soon move between the two plates, leaping alternately from one to the other with great velocity. If, instead of bran, or irregular pieces of other matter, small figures of men or other things cut in paper, and painted, be put upon the plate, they will generally move in an erect position, but will sometimes leap one upon another, or exhibit different postures, so as to afford a pleasing spectacle to an observing company.

In this experiment, both the attraction, and repulsion of Electricity are observed at the same time: for when the upper plate F, which

F, which communicates with the prime Conductor, is electrified, the small bodies placed upon the lower plate, together with that plate, by being within the sphere of action of the electrified upper plate, become actually possessed of a contrary Electricity, leaving their proper quantity of fluid in the lower plate, or the other conducting bodies, that communicate with it. But bodies differently electrified attract each other; therefore the plate F, attracts those light bodies. Now, as soon as these bodies touch the plate F, they become instantly possessed of the same Electricity with the plate, and will therefore be immediately repelled to the lower plate, which is actually electrified with the contrary Electricity, and by touching the light bodies, assists in repelling them again to the upper plate; and thus the plates continue to act upon the light bodies alternately.

That the light bodies cannot be attracted by the upper plate, except they become first possessed of a contrary Electricity, may be observed as follows:—Put the said light bodies upon a clean, and dry pane of glass;
then

then take off the brass plate P, with its stand G, and in its stead put the pane of glass, holding it by one corner; this done, let the wheel of the machine be turned, and you will see that the light bodies are not attracted by the brass plate F; for in this case they have no opportunity of parting with their proper quantity of fluid, and consequently cannot acquire the contrary electricity. But if to the under side of the pane of glass, on which the light bodies are placed, a finger or any other conductor be presented, the light bodies will be instantly attracted by the plate F, and will leap between the glass and plate, in the same manner as between the two plates; for these bodies now deposit their fluid upon the upper surface of the glass plate, whilst the under surface deposits its fluid upon the finger, or other conductor, that has been brought near it*. If this experiment be

* If the above experiment be made with a prime Conductor negatively electrified, the effect will be the same, only the Electricities of the plates are reversed; *i. e.* the upper plate is electrified negatively, and the under plate, by being in the atmosphere of the upper one, is positively electrified.

continued,

continued, the glass will soon be charged †.

EXPERIMENT III.

The Flying-feather, or Shuttle-cock.

The phenomena of electric attraction and repulsion may be represented also with a glass tube, or a charged bottle, and some of them in a manner more satisfactory than with the machine.

Take a glass tube (whether smooth, or rough, is not material), and after having rubbed it, let a small light feather be let out of your fingers at the distance of about eight or nine inches from it. This feather will be immediately attracted by the tube, and will stick very close to its surface for about two or three seconds, and sometimes longer; after which time it will be repelled, and if the tube be kept under it, the feather will continue floating in the air at

† Electric attraction and repulsion takes place also within a vacuum, made by means of common air-pumps.

a considerable distance from the tube, without coming near it again, except it first touches some conducting substance; and if you manage the tube dexterously, you may drive the feather through the air of a room at your pleasure.

The reason of this experiment is obvious; for when the feather is electrified, it cannot approach the tube again, except it first touches some conducting body, because it cannot part with its Electricity when floating in the air, and therefore cannot acquire a contrary Electricity: consequently it must remain in a state incapable of being again attracted by the excited tube.

If it be asked, Why, when the feather is at first attracted by the tube, it sticks for so considerable a time to its surface before it is repelled? the answer is, That the feather being an electric, requireth some time before it acquires any considerable quantity of Electricity.

There is a remarkable circumstance attending this experiment, which is, that if
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the feather be kept at a distance from the tube by the force of electric repulsion, it always presents the same part towards the tube:—You may move the excited tube about the feather very swiftly, and yet the same side of the feather will always be presented to the tube. The reason of this phenomenon is, that the equilibrium of the electric fluid in the parts of the feather, being once disturbed, cannot easily be restored; because the feather is an electric, or at least a very bad Conductor. When the feather has acquired a quantity of Electricity from the tube, it is plain, that by the action of the excited tube, that super-induced electricity will be in the greatest part forced on that side of the feather which happens to be at first the farthest from the tube; hence that part will always afterward be repelled the farthest.

This experiment may be agreeably varied in the following manner:—A person may hold in his hand an excited tube of smooth glass, and another person may hold an excited rough glass tube, a stick of sealing-wax, or in short another electric

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negatively

negatively electrified, at about one foot and a half distance from the smooth glass tube: a feather now may be let go between these two differently-excited electrics, and it will leap alternately from one electric to the other; and the two persons will seem to drive a shuttle-cock from one to the other, by the force of Electricity.

EXPERIMENT IV.

The small insulated Body.

Tie a small body, as for instance a light piece of cork, to a silk thread about eight inches long, and holding the thread by its end, let the small body hang at the distance of about eight inches from the side of the prime Conductor electrified. This small body, if the electrification of the Conductor is not strong, will not be attracted; for, being insulated, it cannot, by depositing its fluid upon, or receiving it from another body (when the prime Conductor is electrified negatively), become contrarily electrified. But if a finger or any conducting substance be presented to
the

the side of the small body which is farthest from the prime Conductor, then the small body will immediately move toward the prime Conductor; for it has deposited its own fluid upon, or acquired some (in case the Conductor is negatively electrified) from the body presented to it; and when this body has touched the prime Conductor, it will be instantly repelled from it, on account of the repulsion existing between bodies possessed of the same kind of Electricity.

Indeed, if this insulated body be very near to the prime Conductor, or the prime Conductor strongly electrified, then the small body will be attracted without presenting to it any conducting substance; but in this case its natural quantity of electric fluid will be either repelled into the contiguous air, or crowded on the part of the body which is farthest from the prime Conductor, if the Conductor is electrified *positively*; but if it is electrified *negatively*, then the additional quantity of fluid, necessary to render the small body overcharged, will be acquired from the air, or

the natural fluid belonging to that body will be all crowded on that side of it, which is nearest to the prime Conductor.

If this small body, instead of the silk, be suspended by a linen thread, it will be attracted at a much greater distance, than in the other case; for now the electric fluid will easily be conducted by the thread, passing upwards, or downwards according as the prime Conductor is electrified, *viz.* negatively, or positively.

EXPERIMENT V.

The electric Well.

Place upon an electric stool a metal quart mug, or some other conducting body nearly of the same form and dimension; then tie a short cork-ball electrometer, of the kind represented fig. 3, * at the end of a silk thread proceeding from the ceiling of the room, or from any other proper support,

* Instead of the electrometer, there may be used any other kind of small conducting body; but that seems best adapted to such experiments.

so that the electrometer may be suspended within the mug, and no part of it may be above the mouth; this done, electrify the mug, by giving it a spark with an excited electric or otherwise, and you will see that the electrometer, whilst it remains in that insulated situation, even if it be made to touch the sides of the mug, is not attracted by it, nor does it acquire any Electricity; but, if whilst it stands suspended within the mug, a Conductor, standing out of the mug, be made to communicate with, or only presented to it, then the electrometer acquires an Electricity contrary to that of the mug, and a quantity of it, which is proportionable to the body with which it has been made to communicate; and it is then immediately attracted by the mug.

The reason why in this experiment the electrometer contracts no Electricity whilst suspended intirely within the cavity of the mug, is, because the Electricity of the mug acts upon the electrometer on all sides, and this has no opportunity of parting with its fluid, when the mug is electrified positively;

nor of receiving any, when the mug is electrified negatively. But, as soon as any Conductor communicates with it, the electrometer becomes immediately possessed of the Electricity contrary to that of the mug; for if the mug be electrified positively, the fluid belonging to the electrometer will be repelled to that body, which communicates with it; and which, being out of the mug, cannot be affected by its Electricity; and if the mug is electrified negatively, it will attract the fluid of the electrometer, which actually receives an additional quantity of it from that conducting body, with which it communicates. The electrometer therefore, becoming always possessed of a contrary Electricity, must necessarily be attracted.

If, by raising the silk thread a little, part of the electrometer, *i. e.* of its linen threads, are lifted just above the mouth of the mug, the balls will be immediately attracted; for then, by the action of the Electricity of the mug, it will acquire a contrary Electricity by giving to, or receiving the electric fluid from, the air above the cavity of the mug.

It has been supposed by some, that the electrometer in the above experiment (or any other small insulated body), hanging in the cavity of an electrified vessel, or the like, is not attracted by the sides of the vessel, because the attraction of Electricity, being as the squares of the distances inversely, cannot affect the electrometer one way more than another; it being demonstrable, that, if to every point of a spherical concave surface, equal centripetal forces are directed, decreasing as the squares of the distances from those points, a small body situated any where within that surface, would remain there, without being attracted one way more than another*.

But to this it may be replied, that the demonstration of the above-mentioned proposition, if it is applicable to spherical, or cylindrical concave surfaces, cannot, however, be applied to every kind of irregular cavities, with which (if they exceed not a certain size) the above experiment succeeds as well, as with the cylindrical cavity of the mug.

* NEWTON's Principia book I. prop. LXX.

In short, in this experiment, when the mug is electrified positively, it is supposed, I. That the superinduced fluid, taking place upon the external surface, occasions the contiguous air to deposit its fluid upon a subsequent quantity of air, and this overcharged air occasions a contiguous circle, or quantity of air, to deposit its fluid upon its subsequent or next adjacent circle, and so on. II. That none of the superinduced fluid can exist upon the internal surface of the mug, and therefore, insulated bodies intirely suspended therein, can acquire no electricity, because the internal air has no opportunity of parting with its own fluid, except a small quantity about the mouth of the mug, where, accordingly, a little Electricity is observable. When the mug is electrified negatively, then it is supposed I. That the deficiency of fluid in the mug is only on its external surface; for the air, contiguous to this surface, by acquiring an additional quantity of electric fluid from the next stratum of air, may become electrified positively. II. That the internal surface of the mug is not undercharged, because its contiguous air, being surrounded by

by the mug, cannot become overcharged, by acquiring an additional quantity of fluid, except a small quantity towards the mouth of the mug, where, accordingly, a little Electricity is observable.

EXPERIMENT VI.

To distinguish the Quality of Electricity in electrified Bodies.

Before we proceed further, it is necessary, that we should describe some practical method of distinguishing the quality of the Electricity in an electrified body, which is absolutely necessary for the right performance of the ensuing experiments. To do this, different methods may be followed, which however are all founded, either upon the electric attraction, and repulsion, or upon the different appearances of the electric light. To find out the quality of Electricity by the different appearances of its light, is a very convenient, and sure method; but the phenomena of attraction and repulsion, afford one much more general, and easy; for sometimes the quantity of Electricity to be observed is so very

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small,

small, that it will give no light, though it may be still capable of attracting or repelling.

The general method to prove whether the Electricity of a body, electrified either by excitation, or communication, is negative, or positive, is, to bring it pretty near to an electrified electrometer D or C fig. 4, and observe whether the body attracts or repels it; for if the electrometer is electrified positively, and the electrified body repels it, then you may conclude that the body is also electrified positively; because bodies, possessed of the same kind of Electricity, repel each other; but if the body presented attracts the Electrometer, then it must be electrified negatively, because there is no electric attraction between bodies, unless they are differently electrified; and as the electrometer is known to be electrified positively, the body is consequently electrified negatively.

This may be also done by electrifying the electrometer negatively; but then the effects are just the contrary, *i. e.* the electrified

fied body, if negative, will repel the electrometer, and if positive, will attract it.

In this experiment, however, it must be observed, that, if the Electricity of the electrified body is much stronger, than that of the electrometer, or the Electricity of the latter stronger, than that of the former, and the electrified body be brought very near the electrometer, then they will attract one another, notwithstanding they are possessed of the same kind of Electricity. Suppose, for instance, that one of the electrometers C is positively electrified, so that its cork-balls may diverge about half an inch, and a glass tube strongly excited be brought near it; when this tube is a foot distant, or more, the electrometer will be a little repelled by it; but if the tube be brought nearer, the cork-balls, that before diverged half an inch, will now converge till they are in contact, and appear, as they actually are, unelectrified; because the action of the excited tube has repelled their superfluous fluid through the threads up to the remotest part of the electrometer. If the tube be presented still nearer, the balls will

will then be attracted by it, because the stronger Electricity of the tube repels not only their superinduced, but also their natural quantity of fluid up the threads, &c. and therefore the balls, becoming negatively electrified, must necessarily be attracted by the tube.

Upon this principle an electrometer may be electrified negatively by means of an electric positively excited; or, on the contrary, it may be electrified positively by an electric possessed of the negative Electricity. Take for instance a glass tube excited positively, and bring it within six or seven inches under the balls of one of the above-said electrometers; in which case the balls of the electrometer will diverge, because their natural quantity of electric fluid has been driven from them to the upper part of the threads by the action of the tube positively excited; so that the balls in reality diverge with negative Electricity. Now, in this state touch the upper part of the threads of the electrometer with your finger, which will take off some of the electric fluid natural to the electrometer; after

after which remove the finger, and immediately after remove the glass tube, and the electrometer will remain electrified negatively, because the excited glass tube did not impart any electric fluid to the electrometer, but only disturbed the equilibrium of the natural quantity of electric fluid, which belonged to the electrometer, and part of which escaped through the finger that touched the electrometer, and which did consequently remain in a negative state.—After the like manner the electrometer may be electrified positively, by means of a body possessed of negative Electricity.

But should a more precise method than the above be required, to determine the quality of the Electricity of an electrified body, the following may be used:—First, electrify one of the electrometers C, placed upon the stand fig. 4, either positively, or negatively, at pleasure: touch it, for instance, with an excited glass tube, so that its balls may repel, and stand about two inches distant from one another; then touch the other electrometer C with the electrified

fied body, that you desire to examine, so that it may be possessed of the same degree of Electricity: Lastly, take either of the two electrometers by the top of the glass handle *a*, disengage it from the arm of the stand, and bring it near the other electrometer; if then, the balls of one electrometer repel those of the other, you may conclude that they are possessed of the same kind of Electricity; but if they attract each other, you may conclude that they were electrified with contrary Electricities; and as you know the Electricity of that electrometer, which was first electrified, you will also know the Electricity of the other electrometer, *i. e.* of the electrified body, with which it was touched.

The above experiment may be also made with the single-thread electrometers; for if they are brought near to one another, when their feathers are electrified, they will, if possessed of the same Electricity, repel, or if possessed of contrary Electricities, attract each other.

EXPERIMENT VII.

The insulated metallic Rod.

Insulate in an horizontal position a metallic rod about two feet long, having blunt ends, and to one of its ends suspend an electrometer, like that represented fig. 3; then bring within three or four inches distance of its other end an excited glass tube. On the approach of the tube, the balls of the electrometer will open, and if you present towards them a body positively electrified, you will perceive, that they diverge with positive Electricity. If the tube is removed, the balls come together again, and no Electricity remains in them, or in the metallic rod. But if while the tube is near one end of the rod, and the balls diverge with positive Electricity, the other end of the rod, viz. that from which the electrometer hangs, be touched with some Conductor, the cork-balls will come immediately together, and they will remain so when the Conductor has been removed;—remove now the excited glass tube,

tube, and the balls will immediately diverge with negative Electricity; which shows that the rod remains undercharged, *i. e.* electrified negatively.

The reason of this experiment is, that the repelling power of the excited tube, driving the fluid of one end of the rod to its other end, *i. e.* to that, with which the electrometer is connected, renders this end electrified positively; but in fact the tube communicates no Electricity to the rod, it only disturbs the equable diffusion of its fluid: in consequence of this, the electrometer, hanging to the overcharged end of the rod, must necessarily appear to be electrified positively; but when the tube is removed, then the electrometer appears again unelectrified: for the fluid, which had by the action of the tube been driven to one end of the rod, now retires to its former situation, and leaves the rod with the electrometer unelectrified.

In the second case, when the balls of the electrometer diverge with positive Electricity, if that end of the rod is touched with
some

some conductor, all its superfluous fluid, which is no other, than that belonging to the opposite end of the rod, will be communicated to that body, with which the rod is touched, and therefore the electrometer remains unelectrified: but now in fact the rod has lost some of its natural quantity of fluid; for if the end of it, that is farthest from the excited tube, remains in its natural state, the other end is undercharged; consequently, when the tube is removed, the small quantity of fluid that remains in the rod will diffuse itself uniformly through it; but this quantity of fluid is less than that naturally inherent in the rod; the rod will therefore remain undercharged, and hence the balls of the electrometer diverge with negative Electricity.

This explanation is the same as that mentioned in the preceding experiment, *viz.* in the method of electrifying an electrometer negatively, with a body possessed of positive electricity, &c.; but as this experiment is the basis, or key, of several others, I shall insist on it a little longer; and, to render its explanation more intelligible and

clear, I shall make use of the following diagram :

A ————— B.

Let the above-mentioned insulated rod be represented by the line A B. When this rod is in its natural state (in respect to Electricity) then the electric fluid belonging to it, is equally diffused throughout the rod. But when the excited tube is brought within three or four inches distance of one of the ends, for instance B, then the fluid, belonging to that end, will be driven to the end A ; which end therefore becomes overcharged, and the end B undercharged ; yet the rod has no more electric fluid now, than it had before ; and when the tube is removed to some distance from the rod, the superfluous fluid, repelled to the end A, returns to its former place, *i. e.* to the end B, and the equilibrium in the rod is restored. But if, when the fluid in the rod is repelled to the end A, this end be touched, the fluid repelled thither will immediately be conducted away by the body that touched it, and will leave the end A
of

of the rod in a natural state; but at the same time, the end B is undercharged; therefore, when the tube is removed, part of the natural fluid belonging to the end A, will go to the end B; and thus the whole rod will remain undercharged, *i. e.* negatively electrified.

If the above experiment be made with an electric negatively electrified (for instance, a rod of sealing-wax instead of the excited glass tube) then the apparent Electricities in the rod will be just the reverse of what they were before; for in this case, that end of the rod to which the electric has been presented, will be overcharged, and the opposite end undercharged; which opposite end, if touched in this state with some conducting substance, will acquire some electric fluid from that substance; and when, after that substance has been removed, the excited electric is also removed, the rod will remain overcharged.

In making this experiment, care must be taken that the end of the rod be very

blunt, and that the electric be not very powerfully excited; otherwise a spark may pass from this to the rod, which renders the experiment precarious.

EXPERIMENT VIII.

The two insulated metallic Rods.

Take two rods of metal, each about a foot long, furnished with knobs at both ends, and, either by silk lines, or by insulating stools, insulate them, so that they may stand horizontally in one direction, and at about half an inch distance from one another. To the middle of each of these rods hang an electrometer, like that represented fig. 3. This done, take an excited glass tube, and bring it to about three inches distance from the knob of one of the rods; on doing which, the electrometers of both rods will appear electrified: keep the tube in that situation for about two seconds, then remove it. The rods now will remain electrified, as appears by the electrometers; the first, *viz.* that to which

the excited tube had been presented, remaining negative, and the other positive.

The reason of this phenomenon is, that when the tube was near the end of one of the rods, the action of its fluid repelling the fluid of that rod, caused it to pass in a spark to the other contiguous rod; on which account, when the tube was removed, the first rod, having lost some of its natural fluid, remained undercharged; and the other rod, acquiring the fluid lost by the former, became overcharged.

In this experiment, if, instead of the glass tube, an electric, negatively excited, be brought near the end of one rod, then that rod will be electrified positively, and the other negatively; for the action of this electric, producing just the contrary effect of the glass tube, instead of repelling the fluid of the first rod into the second, attracts that of the second into the first.

In this experiment the electric does not communicate any electricity of its own, but only disturbs the equilibrium between the fluid of the rods.

C H A P. VI.

Experiments on electric Light.

TH E following experiments require to be made in the dark; for although the electric light, in several circumstances, may be seen in the day-light, yet its appearance in this manner is very confused; and, that the Electrician might form a better idea of its different appearances, it is absolutely necessary to perform such experiments in a darkened room.

E X P E R I M E N T I.

The Star and Pencil of electric Light.

When the electrical machine is in good order, and the prime Conductor is situated with the collector sufficiently near the glass cylinder (which situation I shall call hereafter its proper place) turn the winch, and you will see a lucid star at each of the points of the collector. This star is the
constant

constant appearance of the electric fluid that is entering a point. At the same time, you will see a strong light proceeding from the rubber, and spreading itself over the surface of the cylinder; and, if the excitation of the cylinder is very powerful, dense streams of fire will proceed from the rubber, and, darting round almost half the circumference of the cylinder, will reach the points of the collector *.

If the chain of the rubber is taken off, and a pointed body (as for instance, the point of a needle or a pin) is presented to the back of the rubber, at the distance of about two inches, a lucid pencil of rays will appear to proceed from the point presented, and diverge towards the rubber.

* If the prime Conductor is removed, the dense streams of fire will go quite round the cylinder; reaching from one side of the rubber to the other. — By observing on which side of the cylinder those streams are most copious, it may be easily determined which side of the rubber presses more or less upon the cylinder, or is better covered with amalgam, or, in short, which side is the most or least fit for the excitation of the glass.

This pencil is the constant appearance of the electric fluid issuing from a point; and in fact, it now comes out of the point, in order to supply the rubber, which is constantly exhausted by the cylinder in motion.

If another pointed body be presented to the prime conductor, it will appear illuminated with a star; but if a pointed wire, or other pointed conducting body, be connected with the prime Conductor, it will throw out a pencil of rays; for the prime Conductor being overcharged, the fluid departing from it must, agreeably to the law, form a pencil on that point from which it flies off, and a star on that point which it enters*.

F. BEC-

* It may be asked, why the electric fluid entering a point, causeth the appearance of a star; and when going out of the point, causeth the appearance of a brush of rays? In answer to this question, F. BECCARIA supposes, that the star is occasioned by the difficulty with which the electric fluid is extricated from the air, which is an electric. Suppose, for instance, that a pointed wire is presented to a body positively electrified, the electric fluid is first from that body communicated

F. BECCARIA remarks, that if two equally sharp points are approached to a prime conductor, they will appear luminous at only half the distance at which one of them would have done,

From this experiment may be learned the method of distinguishing the quality of the Electricity of an electrified body, by the appearance of the electric light; for if a needle, or any other pointed body, be presented in the dark, with the point towards a body strongly electrified, it will appear illuminated with a star, when that body is electrified positively, and with a pencil or brush, when it is electrified negatively.

Here it is proper to remark, that if two points (one of which is connected with the

communicated to the air between it and the wire, and then the wire must extricate it from that air. The brush, he supposes to be occasioned by the force with which the electric fluid, going out of a point, runs through the contiguous air to that which is more remote from it; *i. e.* by dividing the contiguous air, and not by affixing itself to it.

prime

prime conductor, or the rubber) are opposed to one another, the appearance of light in both is pretty much the same. Mr. WILCKE remarks, that if a point not electrified, is opposed to another point electrified positively, the cones of light, which otherwise would appear upon them, disappear; but that if a positive cone be opposed to a negative cone, they both preserve their own characteristic properties*.

EXPERIMENT II.

Drawing Sparks.

Let the prime Conductor be situated in its proper place, and electrify it by working the machine; then bring a metallic rod with a round knob at each end, or the knuckle of a finger, within a proper distance of the prime Conductor, and a spark will be seen between that and the knuckle, or knobbed wire. The longer and stronger spark is drawn from that end of the prime

* WILCKE, p. 140.—See BECCARIA's Art. Elect. § 941, and following.

Conductor which is farthest from the cylinder, or rather from the end of the knobbed rod I B, fixed at its end B, fig. 2.; for the electric fluid seems to acquire an impetus by going through a long Conductor, when electrified by a powerful machine *.

This spark (which has the same appearance, whether drawn from a prime Conductor positively, or negatively electrified) appears like a long line † of fire, reaching from the Conductor to the opposed body; and often (particularly when the spark is long, and different conducting substances are near the line of its direction) it will have the appearance of being bended to sharp angles in different places, exactly resembling a flash of lightning. Notwithstanding, however, this extended appearance, which is imputed to the quick passage of the luminous matter, the electric

* The reason of this, I think, is, because that end of the prime Conductor is less influenced by the atmosphere of the excited cylinder.

† It often darts brushes of light sideways, in every direction.

fluid passing from one body to another in a spark, is reasonably thought to proceed in a separate, and nearly globular body.

The direction of the spark often deceives the most experienced Electrician, it seeming sometimes to proceed from one place, and at other times, under the same circumstances, to proceed from the opposite. When the prime Conductor is electrified positively, the spark must certainly proceed from it, and go to the body presented; and when the prime Conductor is electrified negatively, the spark must proceed from the body presented, and go to the Conductor. This, however, we learn by reasoning from other experiments; for the real direction of the spark in the above experiment, is much more rapid in its motion than to admit its form, much less its direction, to be perceived by our eyes.

A longer spark may be drawn from a larger than from a smaller Conductor, except when the Conductor exceeds a certain size. The Conductor, which, when put before an ordinary electrical machine, will give sparks about equal in length to the diameter

diameter of the glass cylinder of the machine, is the largest that can be used to advantage; for a longer spark cannot be obtained, except in some particular cases, *viz.* when some particles of dust, or other extraneous matter, happen to be interposed between the Conductor and the brass ball, or other substance, that is opposed to it, &c. as will appear from the following reasoning:—The circumference of the glass cylinder is nearly equal to three times its diameter. The rubber, with its piece of silk, &c. may occupy about one third part of the said circumference, and consequently the collector of the Conductor, when put in the middle of the remaining surface, at most cannot be farther from the rubber than the length of one diameter of the cylinder, *viz.* one third part of the circumference; therefore it is plain, that if the cylinder could give a spark longer than the diameter of the cylinder, the spark would be darted to the rubber, rather than to any other body placed farther off from the Conductor.—When the rubber of the machine is made to communicate with the earth, by means
of

of imperfect conductors, as a piece of wood, &c. then the Conductor will give a spark generally longer than when perfect conductors are employed for the said communication. In this case it may happen, that a spark some small matter longer than the diameter of the cylinder, might be obtained.

EXPERIMENT III.

The electric Light flashing between two metallic Plates.

Let two persons, one standing upon an insulated stool, and communicating with the prime Conductor, and another standing upon the floor, each hold in one of his hands a metal plate, in such a manner, that the plates may stand back to back in a parallel situation, and about two inches asunder. Let the winch of the machine be turned, and you will see the flashes of light between the two plates so dense and frequent, that you may easily distinguish any thing in the room. By this experiment, the electric light is exhibited in a very copious and beautiful manner, and it bears a striking resemblance to lightning.

EXPERIMENT

EXPERIMENT IV.

To fire inflammable Spirits.

The power of the electric spark to set fire to inflammable spirits, may be exhibited by several different methods; but more easily thus: — Hang to the prime Conductor a short rod, having a small knob at its end, then pour some spirit of wine, a little warmed, into a spoon of metal*; hold the spoon by the handle, and place it in such manner, that the small knob on the rod may be about one inch above the surface of the spirit. In this situation, if, by turning the winch, a spark be made to come from the knob, it will set the spirit on fire.

This experiment happens in the very same manner, whether the Conductor is

* The readiest way to warm the spirits for this experiment, is to set it on fire with a candle when it is in the spoon, and, after it has burned for about two seconds, to blow it out with your breath. In this state it will be found very ready to take fire, even by a small spark.

electrified positively or negatively, *i. e.* whether the spark be made to come from the Conductor, or from the spoon; it being only in consequence of the rapid motion of the spark that the spirits are kindled.

It will be perhaps scarce necessary to remark, that the more inflammable the spirits are, the more proper they will be for this experiment, as a smaller spark will be sufficient to inflame them; therefore, rectified spirit of wine is better than common proof spirit, and æther better than either.

This experiment may be varied different ways, and may be rendered very agreeable to a company of spectators. A person, for instance, standing upon an electric stool, and communicating with the prime Conductor, may hold the spoon with the spirits in his hand, and another person, standing upon the floor, may set the spirits on fire, by bringing his finger within a small distance of it. Instead of his finger, he may fire the spirits with a piece of ice; when the experiment will seem much more surprising.

surprizing. If the spoon is held by the person standing upon the floor, and the insulated person brings some conducting substance over the surface of the spirit, the experiment succeeds as well.

“ Mr. WINCKLER says, that oil, pitch,
 “ and sealing-wax, might be lighted by
 “ electric sparks, provided those substances
 “ were first heated to a degree next to
 “ kindling. To these it must be added,
 “ that Mr. GRALATH fired the smoke of
 “ a candle just blown out, and lighted it
 “ again ; and that Mr. BOZE fired gun-
 “ powder, melting it in a spoon, and first
 “ the vapour that rose from it *.

EXPERIMENT V.

*The artificial Bolonian Stone illuminated
 by the electric Light.*

The most curious experiment to shew the penetrability of the electric light, is

* PRIESTLEY's Hist. of Elect. period VII.

made with the real, or with the artificial Bolonian stone, which is procured more easily, and was invented by the late Mr. J. CANTON. This phosphorus is a calcareous substance, generally used in the form of a powder, which has the property of appearing lucid, when brought into the dark after having been exposed to the light*.

Take

* The method of making this phosphorus is as follows: "Calcine some common oyster-shells" (if they are old, and half calcined by time, such as are commonly found upon the sea-shore, they are, as Mr. W. CANTON observes, so much the better) "by
 " keeping them in a good coal-fire for half an hour,
 " let the purest part of the calx be pulverized, and
 " sifted; mix with three parts of this powder one
 " part of the flowers of sulphur; let this mixture be
 " rammed into a crucible of about an inch and a
 " half in depth, till it be almost full; and let it be
 " placed in the middle of the fire, where it must be
 " kept red-hot for one hour at least, and then set it
 " by to cool: when cold, turn it out of the crucible,
 " and cutting or breaking it to pieces, scrape off,
 " upon trial, the brightest parts; which, if good
 " phosphorus, will be a white powder, and may be
 " preserved by keeping it in a dry phial with a ground
 " stopple."

If this phosphorus, whether in the phial or not, be kept in the dark, it will give no light, but if exposed
 to

Take some of this powder, and, by means of spirit of wine, or æther, stick it all over the inside of a clear glass phial, and stop it with a glass stopper, or a cork and sealing-wax. If this phial be kept in a darkened room (which for this experiment must be very dark) it will give no light, but let two or three strong sparks be drawn from the prime Conductor, when the phial is kept at about two inches distance from the sparks, so that it may be exposed to that light, and this phial will receive that light, and afterwards will appear illuminated for a considerable time.

This powder may be stuck upon a board by means of the white of an egg, so as to represent figures of planets, letters, or any thing else, at the pleasure of the operator, and these figures may be illuminated in the dark, in the same manner as the above-described phial.

to the light, either of the day, or of any thing else, and afterwards brought into a dark place, it will then appear lucid for a considerable time. For farther properties of this phosphorus, see the Phil. Trans. Vol. LVIII.

A beautiful method to express geometrical figures with the above phosphorus, is to bend small glass tubes of about the tenth part of an inch diameter, in the shape of the figure desired, and then to fill them with the phosphorus powder. These may be illuminated in the manner described, and they are not so subject to be spoiled, as the figures represented upon the board frequently are.

The best method of illuminating this phosphorus, and was that Mr. W. CANTON generally used, is to discharge a small electric jar near it.

Paper, after being made dry and rather hot, marble, oyster-shells, and most calcareous substances, especially when burned to lime, have the property of being illuminated by the light given by the discharge of a jar, though not so much as the above-mentioned phosphorus.

EXPERI-

EXPERIMENT VI,

The luminous Conductor.

Fig. 6. Plate I. represents a prime Conductor invented by Mr. HENLY, which shews clearly the direction of the electric fluid passing through it, from whence it is called *the luminous Conductor* *. The middle part E F of this Conductor is a glass tube about eighteen inches long, and three or four inches in diameter. To both ends of this tube the hollow brass pieces F D, B E, are cemented air-tight, one of which has a point C, by which it receives the electric fluid, when set near the excited cylinder of the electrical machine, and the other has a knobbed wire G, from which a strong spark may be drawn ; and from each of the pieces F D, B E, a knobbed wire proceeds, within the cavity of the glass tube. The brass piece F D, or B E, is composed

* An instrument much like this Conductor was some years ago contrived by Dr. WATSON, with which he made several original experiments upon the electric light.

of two parts, *i. e.* a cap F cemented to the glass tube, and having a hole with a valve, by which the cavity of the glass tube may be exhausted of air; and the ball D, which is screwed upon the cap F. The supporters of this instrument are two glass pillars fastened in the bottom board H, like the prime Conductor represented fig. 2. When the glass tube of this Conductor is exhausted of air by means of an air-pump, and the brass ball is screwed on, as represented in the figure, then it is fit for use, and may serve for a prime Conductor to an electrical machine,

If the point C of this Conductor is set near the excited cylinder of the machine, it will appear illuminated with a star; at the same time the glass tube will appear all illuminated with a weak light; but from the knobbed wire, that proceeds within the glass from the piece F D, a lucid pencil will issue out, and the opposite knob will appear illuminated with a star, which, as well as the pencil of rays, is very clear, and discernible among the other light,
that

that occupies the greatest part of the cavity of the tube.

If the point C, instead of being presented to the cylinder, be connected with the rubber of the machine, the appearance of light within the tube will be reversed; the knob which communicates with the piece F D appearing illuminated with a star, and the opposite with a pencil of rays; because in this case the direction of the electric fluid is just the contrary of what it was before; it then going from D to B, and now coming from B and going to D.

If the wires within the tube E F, instead of being furnished with knobs, be pointed, the appearance of light is the same, but it seems not so strong in this, as in the other case.

EXPERIMENT VII.

The conducting Glass Tube.

Take a glass tube of about two inches diameter, and about two feet long; fix to

one of its ends a brass cap, and to the other a stop-cock, or a valve; then by means of an air-pump exhaust it of air. If this tube be held by one end, and its other end be brought near the electrified prime Conductor, it will appear to be full of light, whenever a spark is taken by it from the prime Conductor; and much more so, if an electric jar be discharged through it.

This experiment may also be made with the receiver of an air-pump; take, for instance, a tall receiver, clean and dry, and through a hole at its top insert a wire, which must be cemented air-tight. The end of the wire, that is within the tube, must be pointed, but not very sharp; and the other end must be furnished with a knob. Put this receiver upon the plate of the air-pump, and exhaust it. If now the knob of the wire at the top of the receiver be touched with the prime Conductor *,

* When any thing is to be touched with the prime Conductor, that is not very portable, as the air-pump above-mentioned, the communication between the former and the latter may be made by means of a rod furnished with an electric handle, or the like.

every

every spark will pass through the receiver in a dense and large body of light, from the wire to the plate of the air-pump.

It must be observed, that when the air is very much rarefied, the electric light in it is less dense, though more diffused, and contrarywise.

EXPERIMENT VIII.

The Aurora Borealis.

Take a phial nearly of the shape and size of a Florence flask; fix a stop-cock or a valve to its neck, and exhaust it of air as much as it is possible with a good air-pump. If this glass is rubbed in the common manner used to excite electrics, it will appear luminous within, being full of a flashing light, which plainly resembles the aurora borealis, or northern light. This phial may also be made luminous by holding it by either end, and bringing the other end to the prime Conductor; in this case all the cavity of the glass will instantly appear full of flashing light, which remains
in

in it for a considerable time after it has been removed from the prime Conductor.

Instead of the above-described glass vessel, a glass tube, exhausted of air and hermetically sealed, may be used, and perhaps with better advantage. The most remarkable circumstance of this experiment is, that if the phial or tube, after it has been removed from the prime Conductor (and even several hours after its flashing light hath ceased to appear), be grasped with the hand, strong flashes of light will immediately appear within the glass, which often reach from one of its ends to the other.

The causes on which this experiment depend are two; first, the conducting nature of the vacuum; and, second, the charging of the glass: for when one side of the glass phial is touched with the prime Conductor, the electric fluid, communicated to the outside surface of one side of the phial, causeth the natural fluid belonging to the inside surface to depart from its place, and
go

go to the opposite side of the phial ; and this fluid, passing through the vacuum, causes the light within the phial, which light is more or less subdivided, according as the vacuum is less or more perfect. Now, that part of the phial, which has touched the prime Conductor, is actually charged ; for its outside surface has acquired an additional quantity of electric fluid, and the inside surface has lost part of its own ; but as the outside of the phial has no coating, therefore, when it is removed from the prime Conductor, and is not grasped with the hand, or other Conductor, the charged part of the glass can be discharged only gradually ; that is, whilst its outside surface is communicating its superfluous fluid to the contiguous air, the inside surface acquires the electric fluid from the other end of the phial, which fluid passing through the vacuum, causes that flashing, which is observed for so considerable a time. If the phial is grasped with the hand, its discharge is accelerated, hence the flashes within the phial appear more dense and copious ; yet it cannot be discharged all at once by this operation, because the hand

cannot touch every part of the glass at once.

EXPERIMENT IX.

The visible electric Atmosphere.

G I fig. 2. Plate II. represents the receiver with the plate of an air-pump. In the middle of the plate I F, a short rod is fixed, having at its top a metal ball B nicely polished, whose diameter is nearly two inches. From the top of the receiver, another rod A D with a like ball A proceeds, and is cemented air-tight in the neck C; the distance of the balls from one another being about four inches, or rather more. If, when the receiver is exhausted of air, the ball A be electrified positively, by touching the top D of the rod A D with the prime Conductor or an excited glass tube, a lucid atmosphere appears about it, which, although it consists of a feeble light, is yet very conspicuous, and very well defined; at the same time the ball B has not the least light. This atmosphere does not exist all round the ball A, but reaches from
about

about the middle of it, to a small distance beyond that side of its surface, which is towards the opposite ball B. If the rod with the ball A be electrified negatively, then a lucid atmosphere, like the above-described, will appear upon the ball B, reaching from its middle to a small distance beyond that side of it, that is towards the ball A; at the same time the negatively electrified ball A remains without any light.

The Operator in this experiment, must be careful not to electrify the ball A too much, for then the electric fluid will pass in a spark from one ball to the other, and the experiment will not have the desired effect. A little practice, however, will render the operation very easy and familiar. The exhaustion must also be moderate; for Mr. WILSON, F. R. S. remarked, that no electric light would be seen in a vacuum made by means of one of Mr. SMEATON's air-pumps, which rarefied the air above 2000 times.

By this elegant experiment, which is of the celebrated F. BECCARIA, we have an ocular demonstration of the theory of a
single

single electric fluid; we see that Electricity consists of one uniform, homogeneous fluid, and not two, *viz.* the vitreous, and resinous, as some have supposed; for if the positive and negative Electricity were two distinct fluids, attractive of one another, there should, in the above experiment, always appear two atmospheres, *i. e.* one about the ball A, and another about the ball B; for when the ball A is overcharged with either fluid, it should shew that superfluous fluid on its surface, and this fluid should attract towards the ball A, an atmosphere of the contrary fluid from the ball B. But this, as we observed before, is not the case; for the appearance of the lucid atmosphere is always on one ball, namely, that which is overcharged with the electric fluid; thus, when the ball A is electrified positively, the superfluous fluid is visible on that part of it which is nearest to the ball B, because B, being in a contrary state of Electricity, endeavours to attract it; but, when the ball A is electrified negatively, it will attract the fluid proper to the ball B, which fluid on that account appears

appears upon the surface of B, just in the act of leaping to the ball A.

In order to remove an error, that has been adopted by several writers on Electricity, it will be not amiss in this chapter to mention, that the electric light has all the prismatic colours, as well as the light of the sun. This may be easily experienced by viewing an electric spark through a glass prism *.

* See Dr. PRIESTLEY's History of Electricity, part VIII. sec. XIII. n. XII.

C H A P. VII.

Experiments with the Leyden Phial.

E X P E R I M E N T I.

Of charging, and discharging a Phial in general.

TAKE a coated jar, as D E fig. 2, Plate I, and place it upon the table near the prime Conductor, so that the knob of its wire, and that only, may be in contact with it: fix the quadrant electrometer E fig. 2, upon the prime Conductor, and then turn the winch of the machine. You will observe, that as the jar is charging, the index of the electrometer will rise gradually as far as 90° , or thereabouts, and then rest: when this happens, you may conclude, that the jar has received its full charge. If now you take a discharging rod, and, holding it by the glass handle, apply first one of its knobs to the outside coating of the jar, and then bring the other knob near the knob of the wire of the jar,
or

or near the prime Conductor, that communicates with it, you will hear a report, and see very vivid sparks between the discharging rod and the conducting substances, communicating with the sides of the jar. This operation discharges the jar. If, instead of using the discharging rod, you touch the outside of the jar with one hand, and bring the other hand near the wire of the jar, the same spark and report will follow, but now you will feel a shock, which affects your wrists, elbows, and, if strong, your breast also *. If a number of persons join hands, and the first of them touches the outside of the jar, and the last touches the wire communicating with the inside, they will all feel the shock, and precisely at the same perceivable time. This shock bearing no resemblance to any sensation otherwise felt, cannot consequently be described; and in order that a person may form a just idea of it, he must absolutely feel it.

If many persons lay hold of a metal plate that communicates with the outside of a

* A shock may be given to any single part of the body, if that part only be brought into the circuit.

charged jar, and all together do also hold a metal rod with which the discharge is made, they will all feel the shock; which shews that the discharge has been made through several circuits at once.

The reason of the charging of the phial or jar in this experiment is, that when a superfluous quantity of electric fluid is forced upon the inside surface of the glass, it causeth an equal quantity of fluid, naturally inherent in the glass, to depart from the opposite surface, in consequence of the repulsion natural to the particles of the electric fluid, which repulsion is exerted even through the glass; one side therefore of the glass remains overcharged, and the other undercharged; as soon, therefore, as the communication between the two sides of the jar is compleated, the superfluous fluid on one side of the glass flies violently to the other side, and the rapidity of its motion occasions the spark, the report, &c.

If the coated jar be held by the wire communicating with its inside, and the outside coating be presented to the prime
Conductor,

Conductor, it will be charged as readily as in the other method; but with this difference, that in this case the outside will be positive, and the inside negative.

We have supposed above, that the prime Conductor was electrified positively; but if the experiment be repeated when the Conductor, by being connected with the rubber of the machine, is electrified negatively, the jar would in the same manner be charged; except that in this case the side that touches the prime Conductor would be electrified negatively, and the opposite side positively.

EXPERIMENT II.

To shew that an insulated Jar cannot be charged.

Set a coated jar upon an electric stool; connect its wire, or its outside coating with the prime Conductor, and turn the winch of the machine. You will then observe, that the index of the quadrant electrometer, placed upon the prime Conductor, soon

rises to 90° , seemingly shewing that the jar is charged. Then remove the electric stool with the jar from the prime Conductor, and either with a discharging rod, or with your hands, endeavour to discharge the jar, and you will find, that it is not charged; for no remarkable spark, no shock, nor any other phenomenon of charged glass, will appear.

The reason why in this experiment the inside of the jar could acquire no additional electric fluid, and therefore the jar could acquire no charge, is because the outside could not at the same time part with its own fluid, its communication with the earth being cut off by the electric stool. But repeat this experiment with only this variation, that, by means of a chain or otherwise, the outside of the jar be made to communicate with the table, and you will then find, that the jar will be charged; for in this case the fluid, naturally inherent in the outer surface of the jar, can readily be repelled through the chain, &c. into the table.

Strictly

Strictly speaking, the jar in this experiment will acquire a very slight charge, because some of the electric fluid belonging to its outside will be imparted to the air, &c.

If a jar be insulated, and one side of it, instead of being connected with the earth, be connected with the insulated rubber, whilst the other side communicates with the prime Conductor, the jar will be also charged, and perhaps in a more expeditious manner; for whilst the rubber exhausts one side, the other side is supplied by the prime Conductor. In this manner it is shown, that the jar is charged with its own fluid, *i. e.* the natural electric fluid of one of its sides is, by the action of the machine, thrown on the other side.

EXPERIMENT III.

The preceding Experiment diversified.

To make the above experiment in a clearer, and more satisfactory manner, place the jar upon the stool as before, and with its wire not in contact, but at about

half an inch distance from the prime Conductor; hold the knob of another wire at such a distance from the outside coating of the jar, as the knob of the jar is from the prime Conductor, then let the winch of the machine be turned, and you will observe, that whenever a spark comes from the prime Conductor to the wire of the jar, another spark passes from the outside coating of the jar to the knob of the wire presented towards it; which shews, that as a quantity of electric fluid is entering the inside of the jar, an equal quantity of it is leaving the outside. In this manner the jar becomes charged.

If instead of the knobbed wire, a pointed one be presented to the outside of the jar, it will appear illuminated with a star; and if instead of presenting any wire to the jar, a pointed wire be connected with its coating, it will appear illuminated with a brush of rays (*i. e.* by throwing the electric fluid into the air), which will last as long as the jar is charging.

If the knob of another jar be presented to the outside coating of the insulated jar in the above experiment, it will also be charged; for the fluid, going out of the outside coating of the first jar, *i. e.* that standing upon the stool, will go in the inside of the other jar, and cause the fluid, inherent to the outside of that jar, to depart from its place *.

EXPERIMENT IV.

To shew that the Charge of a Jar, or Glass in general, does not reside in the Coating.

Take a naked phial, and for a coating on the outside stick a piece of tin-foil, with a little tallow or bees-wax, so that it can just adhere to the glass; and for an inside

* It is easy to understand from this experiment, how several phials may be connected together, so that they may be charged all at once, with nearly the same trouble as one is charged. It must, however, be observed, that when several jars are so connected, that the inside of one communicates with the outside of another, &c. they cannot be charged so high, nor so easily, as otherwise; the difficulty increasing nearly in proportion to the number of the jars,

coating use small leaden shot, or quicksilver; lastly, insert through its neck a knobbed wire communicating with the shot or quicksilver.—This done, hold the phial thus coated by its outside coating, and charge it, by presenting its knobbed wire to the prime Conductor. When it is charged, turn it upside down, and let its wire and quicksilver, or shot, fall in a glass receiver; then remove its outside coating also. In this operation the phial does not lose its charge, and if you examine the quicksilver or shot, you will find that it contains no more Electricity than any other like conducting insulated body, which has been in contact with the prime Conductor, would contain. Replace the outside coating again upon the phial, pour the shot or quicksilver again into it, or any other conducting substance, then touch with one hand the outside coating, and with the other, by introducing a finger or a wire, touch the inside non-electric, and you will feel a shock; which will convince you, that the glass has lost very little of its charge by the operation above-mentioned,

The

The same experiment may be more conveniently made by laying a pane of glass upon a metal plate, and covering an equal part of the upper surface with tin-foil, having a silk thread fastened to one of its sides, by which it may be easily taken off, when the glass is charged, and as easily replaced, when required.

EXPERIMENT V.

To prove that the electric Fluid does not expel the Air contained in a Phial.

Through a hole made in the cork that stops a coated phial, introduce a small glass tube open at both ends, and of about one thirtieth part of an inch in diameter; bend that part of the tube, that is out of the phial, in an horizontal situation, and with bees-wax fasten the cork so, that no air can get in or out of the phial, except it passes through the glass tube; lastly, put a small drop of red wine, or ink, in the horizontal part of the tube, so that it may be easily moved through it, by the least rarefaction or condensation of the air within the phial.

If

If this phial thus furnished be charged, by connecting the prime Conductor with its wire, the drop of liquor in the glass tube will not be stirred from its situation; which shews that the electric fluid, im-mitted into the phial, does not exclude any of the air that the phial contains. If the phial be discharged, the drop of liquor in the tube will be often pushed a little out of its place, and afterwards return to its former situation; which shews, that on making the discharge, the air within the phial was a little displaced, or rarefied. This however is to be imputed to some spark, that generally happens within the cavity of the phial, on account that the wire is not in perfect contact with the inside coating*.

* Having repeated this experiment with a small phial, whose charging-piece (as we may call it) was a production of the inside coating, (which was of one piece of tin-foil, stuck to the glass with bees-wax, in consequence of which no spark could happen within the phial) I found that the drop of liquor in the glass tube was not stirred, either in charging or discharging the phial.

EXPERIMENT

EXPERIMENT VI.

The Course of the electric Fluid in the Discharge rendered visible by the Star and Pencil.

When a jar is charged, take a discharging rod having its ends pointed, *i. e.* the discharging rod represented in fig. 10. Plate I. without its knobs, and keep it as represented, fig. 11. that is, in such a situation, that one of its points C may be at about one inch distance from the knob A, and the other point B at an equal distance from the outside coating of the jar; by these means the jar will be discharged silently; and if its inside be electrified positively, you will see, that the point C of the discharging rod is illuminated with a star, and the point B with a pencil; because, in this case, the electric fluid, going from the inside to the outside of the jar, enters the point C, and issues from the point B. But if the jar is electrified negatively on the inside, and consequently positive on the outside, then the pencil of rays will appear upon the point C, and the star upon the

the

the point B; for in this case the electric fluid passes from the outside to the inside of the jar.

N. B. This experiment, as well as any other, in which the electric light is to be observed, requires to be made in the dark.

EXPERIMENT VII.

The Course of the electric Fluid in the Discharge shewn by the Flame of a Wax-taper.

Remove the circular piece of wood E from the universal discharger, represented fig. 5. Plate I. Fix the wires D B, D C, so that their knobs D D may be about two inches distance from one another; and upon the socket F fix a piece of wax-taper lighted, so that its flame may be just in the middle, between the knobs D D. Having disposed the apparatus in this manner, if you connect, by means of a chain or otherwise, the outside of a charged jar with one of the wires C, and bring the knob of the jar to the other wire C, you will observe, that on making

making the discharge, which must pass between the knobs D D, the flame of the wax-taper is always driven in the direction of the electric fluid; that is, it will be blown upon the knob of that wire, which communicates with that side of the jar which is negatively electrified.

In this experiment, the jar must have an exceeding small charge, just sufficient to pass through the interval in the circuit; which experience will presently determine; otherwise the experiment will not succeed, or be perhaps rendered equivocal *.

* If it be asked, Why this experiment does not succeed with a great explosion as well as with a very small one? the answer is, that when a jar highly charged, is brought near one of the wires of the universal discharger, it creates an atmosphere about the knob of the said wire, which atmosphere disturbs the flame of the wax taper, before the actual discharge: besides, the electric fluid in a great explosion, by its elastic nature, passes through the flame of the wax-taper too swiftly to communicate to it any visible motion; in the same manner as a bullet, discharged from a pistol against an open door, makes a hole through the door without shutting it.

EXPERIMENT

EXPERIMENT VIII.

The Course of the electric Fluid in the Discharge, rendered conspicuous by the Motion communicated to a Pith Ball.

Bend a card, length-ways, over a round ruler, so as to form a channel, or semicircular groove *: lay this card upon the circular board E of the universal discharger, represented fig. 5. of Plate I. and in the middle of it put a pith-ball of about half an inch diameter; then at equal distances, about half or three quarters of an inch from the pith-ball, lay the two brass knobs DD. The card being perfectly dry, and rather hot, if you connect, by means of a chain or otherwise, the outside of a charged jar with one of the wires C, and bring the knob of the jar to the other wire C, you

* Instead of the card, a piece of baked wood may be cut in that shape, and painted over with lamp-black and oil; which will answer better than the card, it being much more steady, and not so liable to attract moisture.

will

will observe, that on making the discharge, which must pass between the knobs D D, and over the card, &c. the pith-ball is always driven in the direction of the electric fluid ; *i. e.* it is pushed towards that knob which communicates with the negative side of the jar.

It must be observed, that in this experiment the charge of the jar must be just sufficient to pass through the interval in the circuit ; the card, or piece of baked wood, must be very dry and clean ; and, in short, the disposition of the apparatus, and the performance of this curious experiment, require a degree of nicety that can only be obtained by practice. Without great precaution, it sometimes fails ; but when the operator has once got it to succeed, and follows exactly the same method of operation, he may be sure that the event of the experiment will be constantly as above-described.

EXPERIMENT

EXPERIMENT IX.

The Leyden Vacuum.

Fig. 8 and 9. of Plate I. represent a small phial coated on the outside about three inches up the sides with tin-foil; at the top of the neck of this phial, a brass cap is cemented, having a hole with a valve, and from the cap a wire proceeds a few inches within the phial, terminating in a blunt point. When this phial is exhausted of air, a brass ball is screwed upon the brass cap, so as to defend the valve, and prevent any air from getting into the exhausted glass*. This phial exhibits clearly the direction of the electric fluid, both in charging and discharging; for if it be held by its bottom, and its brass knob be presented to the prime Conductor positively electrified, you will see that the

* The inside of this phial requires no coating, because, as the electric fluid pervades vacuum, it can pass freely from the wire to the surface of the exhausted glass, without the help of a non-electric coating.

electric fluid causeth the pencil of rays to proceed from the wire within the phial, as represented fig. 9. and if it is discharged, a star will appear in the place of the pencil, as represented in fig. 8. But if the phial is held by the brass cap, and its bottom be touched with the prime Conductor, then the point of the wire, on its inside, will appear illuminated with a star when charging, and with a pencil when discharging. If it be presented to a prime Conductor electrified negatively, all these appearances, both in charging and discharging, will be reversed.

This experiment of the Leyden vacuum, together with the two preceding ones, namely the seventh and eighth of this chapter, are inventions of Mr. HENLY.

S

EXPERIMENT

EXPERIMENT X.

To pierce a Card, and other Substances, with the electric Explosion.

Take a card, a quire of paper, or the cover of a book, and keep it close to the outside coating of a charged jar; put one knob of the discharging rod upon the card, quire of paper, &c. so that between the knob and coating of the jar, the thickness of that card, or quire of paper only is interposed; lastly, by bringing the other knob of the discharging rod near the knob of the jar, make the discharge; and the electric matter rushing through the circuit, from the positive to the negative surface of the jar, will pierce a hole (or perhaps several) quite through the card, or quire of paper *. This hole has a bur raised on

* The hole, or holes, are larger or smaller, according as the card, &c. is more damp or more dry. It is remarkable, that if the nostrils are presented to it, they will be affected with a sulphureous, or rather a phosphoreal smell, just like that produced by an excited Electric.

each side, except the card, &c. be pressed hard between the discharging rod and the jar; which shows that the hole is not made in the direction of the passage of the fluid, but in every direction from the center of the resisting body.

If this experiment be made with two cards instead of one, which however must be kept very little distant from one another *, each of the cards, after the explosion, will be found pierced with one or more holes, and each hole will have burs on both surfaces of each card.

If, instead of paper, a very thin plate of glass, rosin, sealing-wax, or the like, be interposed between the knob of the discharging rod, and the outside coating of the jar, on making the discharge, this will be broken in several pieces.

Small insects may also be killed in this manner; they may be held between the

* This may be easily effected by bending one of the cards a little.

outside coating of the jar, and the knob of the discharging rod, like the above card; and a shock of a common phial sent through them, will instantly deprive them of life, if they are pretty small; but if larger, they will be affected in such a manner, as to appear quite dead on first receiving the stroke, but will, after some time, recover: this, however, depends on the quantity of the charge sent through them.

If a shock is sent through a lump of white sugar, strong enough to break the sugar, the shock will illuminate every piece of it, so as to afford a beautiful experiment in the dark. — The sugar will give light for about a minute afterwards.

EXPERIMENT XI.

To shew the Effect of the Shock sent over the Surface of a Card or other Substances.

Put the extremities of two wires upon the surface of a card, or other body of an electric nature, so that they may be in
one

one direction, and about one inch distance from one another; then, by connecting one of the wires with the outside of a charged jar, and the other wire with the knob of the jar, the shock will be made to pass over the card or other body.

If the card be made very dry, the lucid track between the wires will be visible upon the card for a considerable time after the explosion. If a piece of common writing-paper be used instead of the card, it will be torn by the explosion into very small bits.

If instead of the card, the explosion is sent over the surface of a piece of glass, this will be marked with an indelible track, which generally reaches from the extremity of one of the wires to the extremity of the other. In this manner the piece of glass is very seldom broken by the explosion. But Mr. HENLY has discovered a very remarkable method to increase the effect of the explosion upon the glass; which is by pressing with weights that part of the glass, which lies between the two

wires, (*i. e.* that part, over which the shock is to pass). He puts first a thick piece of ivory upon the glass, and places upon that ivory a weight at pleasure, from one quarter of an ounce, to six pounds: The glass in this manner is generally broken by the explosion into innumerable fragments, and some of it is absolutely reduced into an impalpable powder. If the glass is very thick, and resists the force of the explosion, so as not to be broken by it, it will be found marked with the most lively prismatic colours, which are occasioned by very thin laminæ of the glass, in part separated from it by the shock. The weight laid upon the glass is always shock by the explosion, and sometimes it is thrown quite off from the ivory*. This experiment may be most conveniently made with the universal discharger. Fig. 5. of Plate I.

* If small representations of houses, &c. be laid upon a board, placed on the piece of ivory; that, being shock by the explosion, will give a very natural idea of an earthquake.

EXPERIMENT XII.

To shew the Direction of the electric Fluid in the Discharge, by causing the Shock to go over the Surface of a Card.

Dispose the apparatus in the manner described in the preceding experiment, but with this difference, that instead of laying the extremities of both wires upon the same side of the card, one of them be placed under the card; then send a shock through the said wires, as in the preceding experiment, and you will observe, that the electric fluid will run over that surface of the card, upon which lies the extremity of that wire, which is connected with the positive side of the jar; and in order to pass to the extremity of the other wire, it will break a hole through the card just over the extremity of that wire, which is connected with the negative side of the jar.

This excellent experiment, which shows the direction of the electric fluid in the discharge of a jar, is a discovery of Mr. LULLIN of Geneva.

N. B. With very large jars, this experiment has been observed to pierce several holes, and in such manner as to render the experiment not satisfactory.

EXPERIMENT XIII.

To swell the Clay, and break small Tubes with the electric Explosion.

Roll up a piece of soft tobacco-pipe clay in a small cylinder C D fig. 4. Plate II. and insert in it two wires A, B, so that their ends within the clay may be about a fifth part of an inch from one another. If a shock be sent through this clay, by connecting one of the wires A, or B with the outside of a charged jar, and the other with the inside, it will be inflated by the shock, *i. e.* by the spark, that passes between the two wires, and after the explosion will appear as represented fig. 5. If the shock sent through it is too strong, and the clay not very moist, it will be broken by the explosion, and its fragments scattered in every direction.

To

To make this experiment with a little variation, take a piece of the tube of a tobacco-pipe, about one inch long, and fill its bore with moist clay, then insert in it two wires, as in the above rolled clay, and send a shock through it. This tube will not fail to burst by the force of the explosion, and its fragments will be scattered about to a great distance.

If instead of clay, the above-mentioned tube of the tobacco-pipe, or a glass tube, (which will answer as well) be filled with any other substance, either electric or non-electric, inferior to metal, on making the discharge, it will be broken in pieces with nearly the same force.

This experiment is the invention of Mr. LANE, F. R. S.

EXPERIMENT XIV.

To show the Course of the electric Fluid by the spontaneous Discharge.

Take a coated phial of a small size, and if the naked part of it, *i. e.* from its outside

side coating to the cork, is very dry, breathe upon it once or twice, so as to render it slightly damp; then holding the phial by its outside coating, present its knob to the prime Conductor, while the machine is in action, and you will see, that after the phial has received a small charge, a beautiful brush of rays will proceed from the cork, which, after going a little way into the air, turns its course towards the outside coating of the phial. If the phial, instead of the prime Conductor, be presented to the insulated rubber, then the brush, instead of proceeding from the cork, will issue from the outside coating, and direct its course towards the cork or wire of the phial; showing beyond a doubt the truth of the hypothesis of a single electric fluid.

This experiment, which is of Mr. HENLY, requires a nicety of operation, without which it will not succeed as above described. The quantity of moisture upon the phial, and the quantity of Electricity communicated by the machine, must be of a degree,

a degree, which nothing but practice can determine.

E X P E R I M E N T XV.

To make the electric Spark visible in Water.

Fill a glass tube of about half an inch diameter, and six inches long, with water, and to each extremity of the tube adapt a cork, which may confine the water; through each cork insert a blunt wire, so that the extremities of the wires within the tube may be very near one another; lastly, connect one of these wires with the coating of a small charged phial, and touch the other wire with the knob of it; by which means the shock will pass through the wires, and cause a vivid spark to appear between their extremities within the tube. In performing this experiment care must be taken, that the charge be exceedingly weak, otherwise the tube will burst.

C fig. 14. Plate II. represents a common drinking-glass almost full of water. A B are two knobbed wires so bent, that
their

their knobs may be within a little distance of one another in the water. If one of these wires be connected with the outside coating of a pretty large jar, and the other wire be touched with the knob of it; the explosion which must pass through the water from the knob of one of the wires to that of the other, will disperse the water, and break the glass with a surprising violence. This experiment is very dangerous, if not conducted with great caution.

F. BECCARIA constructed a small mortar, into which a drop of water was put, between the extremities of two wires which went through the sides of the mortar, and a wooden ball was applied over the drop of water; then a charged jar being discharged through the wires of the mortar, and consequently through the drop of water, rarefied the latter, and drove the ball out with considerable force. Mr. LULLIN produced a greater effect by making the discharge through oil instead of water. *Dissertatio Physica*, p. 26.

EXPERIMENT XVI.

*To prove that the electric Spark displaces
and rarefies the Air.*

Fig. 3. Plate II. represents an instrument, which the inventor, Mr. KINNER-SLEY, calls the *electrical Air Thermometer*, it being very useful to observe the effects of the electric explosion upon air. The body of this thermometer consists of a glass tube A B, about ten inches long, and nearly two inches diameter, and closed air-tight at both ends by two brass caps. Through a hole in the upper cap, a small tube H A, open at both ends, is introduced in some water at the bottom B of the large tube. Through the middle of each of the brass caps, a wire F G, E I is introduced, having a brass knob within the glass tube, and by sliding through the caps, they may be set at any distance from one another. This instrument is, by a brass ring C, fastened to the pillar of the wooden stand C D, that supports it. When the air within the
tube

tube A B is rarefied, it will press upon the water at the bottom of the tube, which will consequently rise in the cavity of the small tube; and as this water rises higher or lower, so it shows the greater or less rarefaction of the air within the tube A B, which has no communication with the external air.

If the water, when this instrument is to be used, is all at the bottom of the large tube, (*i. e.* none of it is in the cavity of the small tube) it will be proper to blow with the mouth into the small tube, and thus cause the water to rise a little in it; where, for better regulation, a mark may be fixed.

Bring the knobs G I of the wires I E, F G into contact with one another, then connect the ring E, or F with one side of a charged jar, and the other ring with the other side, by which operation a shock will be made to pass through the wires F G, I E, *i. e.* between the knobs E I. In this case you will observe, that the water in the small tube is not at all moved from
the

the mark ; which shows, that the passage of the electric fluid through Conductors sufficiently large, occasions no rarefaction, nor displaces the air about them.

Put the knobs G, I a little distant from one another, and send a shock through them as before, and you will see that the spark between the two knobs, not only displaces, but rarefies considerably the air ; for the water will be suddenly pushed almost to the top of the small tube, and immediately it will subside a little, as for instance as far as H ; which is occasioned by the sudden displacing and replacing of the air about the place, where the spark appeared within the tube A B. After that the water has subsided suddenly from the first rising, it will then gradually and slowly come down to the mark at which it stood before the explosion ; which is the effect of the air that was rarefied, and which gradually returns to its former temperature.

If this experiment be made in a room, where the degree of heat is variable, then
proper

proper allowance must be made for this circumstance, in estimating the event of the experiment; for the electrical air thermometer is affected by heat, or cold in general, as well as by that caused by an electric spark.

EXPERIMENT XVII.

To fire Gun-powder.

Make a small cartridge of paper, and fill it with gun-powder, or else fill the tube of a quill with it; insert two wires, one at each extremity, so that their ends within the quill, or cartridge, may be about one fifth of an inch from one another; this done, send the charge of a phial through the wires, and the spark between their extremities, that are within the cartridge, or quill, will set fire to the gun-powder. If the gun-powder be mixed with steel-filings, it will take fire more readily, and with a very small shock.

EXPE-

EXPERIMENT XVIII.

To light a Candle by the discharge of a Jar.

Take a wire of the size of a common knitting-needle, and by means of a small flexible wire or a chain, let one end of it communicate with the outside of a jar, that at least contains about 10 inches of coated surface. To the other end of the thick wire some cotton must be twisted, but very loosely, so as to form a head round, and to conceal the extremity of the wire entirely. This head of cotton must be rolled in powder of lycopodium, or, which answers better, in powder of rosin; by which means a good deal of the powder will stick to the cotton:—this done, the jar is charged, and then the head of cotton, &c. is brought towards its knob rather quickly, so as to cause the jar to discharge through the cotton, by which means the cotton will be instantly set on fire, and will last long enough to light a candle thereby. — This is a very striking experiment, contrived by Dr. INGENHOUSZ.

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EXPE-

EXPERIMENT XIX.

To strike Metals into Glass.

Take two slips of common window-glass about three inches long, and half an inch wide; put a small slip of gold, silver, or brass leaf, between them, and tie them together, or else press them together between the boards of the press H, belonging to the universal discharger, fig. 5, Plate I. leaving a little of the metallic leaf out between the glasses at each end; then send a shock through this metallic leaf, and the force of the explosion will drive part of the metal into so close a contact with the glass, that it cannot be wiped off, or even be affected by the common menstrua, which otherwise would dissolve it.

In this experiment the glasses are often shattered to pieces; but whether they are broken or not, the indelible metallic tinge will always be found in several places, and sometimes through the whole length of both glasses.

EXPERIMENT XX.

To stain the Paper, or Glass.

Lay a chain, which forms a part of the circuit between the two sides of a charged jar, upon a sheet of white paper, and if a shock be sent through it, the paper will be found stained with a blackish tinge at every juncture of the links. If the charge be very large, the paper, instead of being stained with spots, is burnt through. If the chain be laid upon a pane of glass, instead of paper, the glass will often be found stained with spots in several places, but (as might be expected) not so deep as the paper.

If this experiment be made in the dark, a spark will be seen at every juncture of the links; and if the links are small, and the shock pretty strong, the chain will appear illuminated like a line of fire; which shows that the electrical fluid meets with some resistance in passing from one link of the chain to another.

EXPERIMENT XXI.

The lateral Explosion.

If a jar be discharged with a discharging rod that has no electric handle, the hand that holds it, in making the discharge, feels some kind of shock, especially when the charge is considerable.—In other words: A person, or any conducting substance, that is connected with one side of a jar, but forms no part of the circuit, will feel a kind of shock, *i. e.* some effect of the discharge. This may be rendered visible in the following manner. Connect with the outside of a charged jar a piece of chain; then discharge the jar through another circuit, as for instance, with a discharging rod in the common way, and the chain that communicates with the outside of the jar, and which makes no part of the circuit, will appear lucid in the dark, *i. e.* sparks will appear between the links; which shews that the electric fluid natural to that chain, must by some means have been

been disturbed. This chain will also appear luminous, if it is not in contact with the outside of the jar, but only very near it; and on making the discharge, a spark will be seen between the jar and the end of the chain near it. This electrical appearance out of the circuit of a discharging jar, is that which we call the *lateral Explosion*: and to make it appear in the most conspicuous manner, observe the following method, which is of Dr. PRIESTLEY.

When a jar is charged, and stands upon the table as usual, insulate a thick metallic rod, and place it so that one of its ends may be contiguous to the outside coating of the jar; and within about half an inch of its other end, place a body of about six or seven feet in length, and a few inches in breadth; then put a chain upon the table, so that one of its ends may be about one inch and a half distant from the coating of the jar; at the other end of the chain apply one knob of the discharging rod, and bring the other knob to the wire of the jar in order to make the explosion. On making the discharge in this manner,

a strong spark will be seen between the insulated rod, which communicates with the coating of the jar, and the body near its extremity, which spark does not alter the state of that body in respect to Electricity; hence it is imagined, that this lateral spark flies from the coating of the jar, and returns to it at the same instant, allowing no perceptible space of time, in which an electrometer can be affected. Whether this lateral explosion is received on flat and smooth surfaces, or upon sharp points, the spark is always equally long and vivid.

The cause of this phenomenon seems to be the interruption in the circuit, made by introducing bad Conductors into it; for, as this interruption is greater or less, so the lateral explosion is more or less considerable.

C H A P. VIII.

Experiments with other charged Electrics.

THAT the experiments made with other charged electrics are similar to those made with charged glass, is very evident: since it has been observed above in the First Part, and also in the experiments already described, that the property of being charged, of exploding, &c. is not inherent in glass, as glass, but, as being impervious to the electric fluid; and in consequence, it must be common to all such substances, which, like glass, are impervious to that fluid: therefore, under the title of experiments with other electrics, I mean to describe experiments, not of a different nature from the above-mentioned, but only the manner of coating and using other electrics, which are not so manageable as glass, but at the same time, have some peculiar advantages. These methods I shall reduce to three, *i. e.* first, that of making the noble experiment of

charging a plate of air; secondly, the method of coating resinous substances; and lastly, a method of trying other electrics, that are in a fluid state.

EXPERIMENT I.

To charge a Plate of Air.

Take two smooth circular boards, quite plain, and each about three or four feet in diameter; coat one side of each with tin-foil, which should be pasted down, and burnished, and turned over the edge of the board. These boards must be both insulated, parallel to one another, in an horizontal position; they must be turned with their coated sides towards each other, and should be placed in such a manner as to be easily removed to or from each other; to do which, it will be proper to fix to one of the boards a strong supporter, of glass or baked wood, and to suspend the other by silk strings from the cieling of the room; from which, by a proper pulley, it may be lowered or raised, so as to be at any distance required from the lower board, which may be placed upon the table.

When

When these boards are placed in the manner above described, and at about one inch distance from one another, they may be used exactly as the two coatings of a pane of glass. If one of the boards is connected with the electrified prime Conductor, and the other be left insulated, they will receive no charge, agreeable to the second experiment of the preceding chapter; and if after some time you touch them, you will receive only a spark from the upper board, in consequence of its being connected with the electrified prime Conductor. If, whilst one of the boards is receiving Electricity, the other communicates with the earth, then the plate of air between them will be charged, like a coated plate of glass; for that board which communicates with the earth will acquire an Electricity contrary to that of the other board; and if you touch them, *i. e.* make a communication between them, they will explode, give the shock, &c. similar to a charged jar.

In this experiment it cannot be expected, that such an explosion, and with such a force,

force, will be produced, as by an equal surface of coated glass; for here the coatings cannot be brought so near one another as to render them capable of a high charge, because the plate of air, being much less compact than glass, may be easily broken by the force of the charge, *i. e.* it may easily discharge itself. Notwithstanding, however, that a plate of air is not capable of receiving a very high charge, yet this experiment has a great advantage, which is, that here we may see what presses between the two coatings, either in charging or discharging the plate of air; and we may introduce several things into the substance of this coated electric, which produce several remarkable appearances. By this experiment the true state of the earth, when covered by electrified clouds, may be represented exceedingly well; and several meteors, that happen in that state, and which are thought to be effects of Electricity, may be imitated; such as water-spouts and whirlwinds, besides the well-known electrical phenomena, thunder and lightning.

In

In order to represent a water-spout, as it is often observed at sea, place the two boards at about two inches distance from one another; put a large drop of water about the middle of the lowest of them, and fix a metallic ball, or any other piece of metal that is somewhat spherical *, to the upper board, just opposite to, and at about half an inch distance from the surface of the water. If in this situation the upper board be electrified, whilst the lower communicates with the earth, the water, which represents the sea, will be attracted by the metallic ball, which represents a cloud, and rising nearly in a conical body, will afford a pretty good representation of the water-spout †.

The

* The metallic covering of some kind of coat-buttons answers exceedingly well, and may be pasted on the tin-foil coating of the board.

† The knob of a charged bottle, being brought near the water in a metal plate, or common earthen-ware faucer, shows this experiment in a simple and beautiful manner. If a large drop of water be placed upon the knob of an insulated charged bottle, and the knob of another bottle, charged with the contrary Electricity, be brought near the drop of water, it will be squirted

The appearance of a whirlwind is but seldom, and by chance to be observed. The bran between the two plates F, P, fig. 2, Plate I. is often whirled like the dust in a whirlwind; but there is no certain rule, that I know, for producing this phenomenon.

In order to succeed in this experiment, Mr. BECKET directs to place the boards above-mentioned about four or five inches asunder, and to put some bran, and very small bits of paper about the center of the lower board. If in this situation the upper board be connected with the electrified prime Conductor, and the lower be either connected with the ground or with the rubber of the machine, the bran, and bits of paper will be attracted and repelled, alternately, by the boards. “ But (says “ Mr. BECKET *) the most surprizing appearance in this experiment, and what “ gives it the most exact resemblance of a

squirting away in a curious manner, particularly if the coating of the insulated bottle be touched at the same time.

* In his Essay on Electricity, p. 141.

“ whirl-

“ whirlwind, is that sometimes, when the
 “ Electricity is very strong, a quantity of
 “ the paper and bran will accumulate in
 “ one place, forming a kind of column
 “ between the boards, and suddenly ac-
 “ quire a swift horizontal motion, moving
 “ like a whirling pillar to the edge of the
 “ boards, and from thence fly off, and be
 “ scattered about the room to a consider-
 “ able distance. I own I am entirely at a
 “ loss to account for this extraordinary ap-
 “ pearance—I call it extraordinary, be-
 “ cause it but seldom occurs, and seems to
 “ depend either on a certain degree of at-
 “ traction, quantity of the bran, or dis-
 “ tance between the boards; and I could
 “ seldom get it to succeed perfectly but by
 “ accident.”

The phenomena of thunder and light-
 ning are exhibited at the same time by a
 spontaneous discharge of the plate of air;
 which may be easily produced by setting
 the boards at about an inch distance from
 each other, and electrifying them strongly.

EXPERIMENT II.

To coat resinous Electrics.

The best method to coat such electrics as rosin, sealing-wax, &c. that can easily be melted, is first to put a circular piece of tin-foil, about two inches less in diameter than the plate you intend to make, upon a marble table; then, to pour over it the electric just melted. This may be spread and flattened by pressing it with a pane of glass, or any thing that is even and smooth; afterwards, another piece of tin-foil, equal to the former, is to be stuck upon the electric, which may be done by pressing it gently with a hot iron; and then the plate, which may be easily separated from the marble table, will be fit for use.

EXPERIMENT III.

To insulate fluid Electrics.

Take a large earthen dish, flat at the bottom, and stick within it a piece of tin-foil

foil about an inch shorter than the flat part of the dish all around, and through a small hole, made in the bottom of the dish, introduce a slender wire, which must communicate with the tin-foil; then pour into the dish some melted tallow, or other electric substances that you desire to try; lastly, let a round brass plate *, equal to the tin-foil stuck in the dish, and either proceeding from a glass arm or from the prime Conductor, just touch the surface of the electric in the dish, and let it stand parallel, and opposite to the tin-foil stuck in its bottom. In this manner the plate of liquid electric is coated, and may be easily subjected to experiments.

Plates of other consistent electrics, that cannot easily be melted, may be coated in the same manner as a plate of glass; and some of them will be found to answer as well, if not better than glass.

* The brass plate F, fig. 2. of Plate I. may be very useful for this purpose.

C H A P. IX.

Experiments on the Influence of Points, and the Usefulness of pointed metallic Conductors, to defend Buildings from the Effects of Lightning.

MY reader, in the course of this work, must have observed in several of the experiments already described, the remarkable property that points have, both of throwing off and receiving *silently* the electric fluid; but in this chapter I shall describe some more curious experiments of this kind, by which the influence of points, in respect to Electricity, may be better understood, and which may, in a more particular manner, demonstrate the utility of metallic Conductors to houses, or piles of building, in order to preserve them from the damage often occasioned by a stroke of lightning; which is one of the greatest benefits that mankind has received from the science of Electricity.

E X P E R I M E N T

EXPERIMENT I.

To discharge a Jar silently.

When a large jar is fully charged, which would give a terrible shock, put one of your hands in contact with its outside coating; with the other hold a sharp-pointed needle, and, keeping the point directed towards the knob of the jar, proceed gradually near it, until the point of the needle touches the knob. This operation discharges the jar entirely, and you will either receive no shock at all, or so small a one as can hardly be perceived. The point of the needle, therefore, has silently and gradually drawn all the superfluous fluid from the inside surface of the electric jar.

EXPERIMENT II.

Drawing the Electricity from the prime Conductor by a Point.

Let a person hold the knob of a brass rod at such a distance from the prime
U Conductor,

Conductor, that sparks may easily fly from the latter to the former, when the machine is in motion. Then let the winch be turned, and, while the sparks are following one another, present the sharp point of a needle at nearly twice the distance from the prime Conductor, that the knobbed rod is held; and you will observe that no more sparks will go to the rod;—remove the needle entirely, and the sparks will be seen again;—present the needle, and the sparks disappear; which evidently shows, that the point of the needle draws off *silently* almost all the fluid that the cylinder throws upon the prime Conductor.

If the needle be fixed upon the prime Conductor with the point outward, and the knob of a discharging rod, or the knuckle of a finger, be brought very near the prime Conductor, though the excitation of the cylinder may be very strong, yet you will perceive that no spark, or only an exceeding small one, can be obtained from the prime Conductor.

EXPERIMENT

EXPERIMENT III.

The electric Fly.

Fix the fly, described in the third chapter, upon the prime Conductor, as represented by D, fig. 2 of Plate I; then turn the winch of the machine, and the fly will immediately begin to move round in an horizontal position, and in the direction of the letters *a b c d*; *i. e.* contrary to the direction of the points of the wires. If the experiment is repeated with a Conductor negatively electrified, the fly will turn the same way as before, *viz.* in the direction of the letters *a b c d*. The reason of this experiment depends upon the repulsion existing between bodies possessed of the same Electricity; for whether the fly is electrified positively or negatively, the air opposite to the points of the wires (on account of the points easily transmitting Electricity) acquireth a strong Electricity, analogous to that of the points; and therefore the air and the points must repel each other. This explanation is confirmed, by

U 2 observing

observing that the above fly not only does not move in vacuo ; and even, if placed under a close receiver, it will turn but for a little while, and then stop ; for the quantity of air contained in the receiver, may become readily, and equally electrified *.

EXPERIMENT IV.

The electrified Cotton.

Take a small lock of cotton, extended in every direction as much as conveniently can be done, and by a linen thread about

* If, when the fly under the close receiver is stopped, you put the end of a finger on the outside of the glass, opposite to one of the points of the fly, this will move again briskly ; and by altering the position of your finger occasionally round the glass, you may continue its action a considerable time, *viz.* till most of that part of the glass is charged. In this case, when the finger is applied on the outside of the receiver, the glass losing part of its natural electric fluid from the outside (*i. e.* if the fly is electrified positively, or *vice versa*, if negatively) receives the fluid of the electrified air on its inside surface ; hence this air is put in a state of being again electrified by the point of the fly, which renews the motion of the fly.

five or six inches long, or by a thread drawn out of the same cotton, tie it to the end of the prime Conductor; then let the winch of the machine be turned, and the lock of cotton, on being electrified, will immediately swell, by repelling its filaments from one another, and will stretch itself towards the nearest Conductor. In this situation, let the winch be kept turning, and present the end of your finger, or the knob of a wire, towards the lock of cotton, which will then immediately move towards the finger, and endeavour to touch it; but take with the other hand a pointed needle, and present its point towards the cotton, a little above the end of the finger, and you will observe the cotton immediately to shrink upward, and move towards the prime Conductor. Remove the needle, and the cotton will come again towards the finger. Present the needle, and the cotton will shrink again: which clearly shews, that the needle, being sharp-pointed, draws off the electric fluid from the cotton, and puts it in a state of being attracted by the prime Conductor; which could not be effected by a wire having a

blunted end, or a round ball for its termination.

EXPERIMENT V.

The electrified Bladder.

Take a large bladder, well blown, and cover it with gold, silver, or brass leaf, sticking it with gum-water; suspend this bladder at the end of a silk thread, at least six or seven feet long, hanging from the ceiling of the room, and electrify the bladder, by giving it a strong spark with the knob of a charged bottle: this done, take a knobbed wire, and present it to the bladder when motionless, and you will perceive, that as the knob approaches the bladder, the bladder also moves towards the knob, and when nearly touching it, gives it the spark, which it received from the charged phial, and thus it becomes un-electrified. Give it another spark, and, instead of the knobbed wire, present the point of a needle towards it, and you will perceive that the bladder will not be attracted by, but rather recede from the point,

point, especially if the needle be very suddenly presented towards it.—This is one of Mr. HENLY's experiments.

Before we proceed to the practical use of pointed Conductors to buildings, in order to defend them from lightning (which is nothing more than the proper application of the preceding experiments) it will be proper to say something in explanation of the above property of points, which has lately occasioned several controversies. In order to this, it should be remembered, that the electric fluid superinduced upon an insulated body, is confined upon that body by the air which surrounds it. Further, that Electricity, by being continually communicated to the air, which is never a perfect electric, is gradually dissipated; from whence follows this very evident principle, *i. e.* that as a greater or less quantity of air is contiguous to a given quantity of electrified surface, so that surface loseth its Electricity sooner or later. Suppose, for instance, that a pointed needle is fixed upon the prime Conductor; mark a dot upon any part of the prime Conductor,

tor, which may be nearly equal to the point of the needle, and then electrify the prime Conductor. Now it is evident to bare inspection, that although the point of the needle and the dot, &c. are of equal surfaces, yet the former is exposed to a quantity of air, which almost entirely furrounds it, and which is vastly greater than the air contiguous to the latter: hence, the Electricity, communicated to the prime Conductor, is dissipated more easily from the point of the needle than from the dot, or any other part of the prime Conductor. Besides, the air about the point may more easily be moved, in consequence of the electrical repulsion, than at any other part of the surface of the prime Conductor, and new air, *i. e.* unelectrified air, passes more frequently by it, which taking always part of the Electricity of that body, promotes also its dissipation.

In the same manner may be understood, why the Electricity is more easily dissipated at sharp edges and corners, than at flat ones; for as the surfaces of bodies in general are more or less plain, so they are exposed

exposed to a less or greater quantity of air, and participate more or less of the nature and properties of points.

When the pointed body is negatively electrified, it is for the same reason that it acquires the electric fluid through the point, easier than through any other part of its surface; *i. e.* because the point exhibiting the least surface to the greatest quantity of free air, has the greatest number of particles of air, from which it can extract the electric fluid*.

EXPERIMENT VI.

The Thunder-house.

Fig. 1. of Plate II. is an instrument representing the side of a house, either furnished with a metallic Conductor, or not; by which both the bad effects of lightning striking upon a house not properly secured, and the usefulness of metallic Con-

* For a more particular explanation of the above-mentioned property of points, see BECCARIA's Artificial Electricity.

ductors,

ductors, may be clearly represented. A is a board about three quarters of an inch thick, and shaped like the gable-end of a house. This board is fixed perpendicularly upon the bottom board B, upon which the perpendicular glass pillar C D is also fixed, in a hole about eight inches distant from the basis of the board A. A square hole, I L M K, about a quarter of an inch deep, and nearly one inch wide, is made in the board A, and is filled with a square piece of wood, nearly of the same dimensions. I mention nearly of the same dimensions, because it must go so easily into the hole, that it may drop off by the least shaking of the instrument. A wire, L K, is fastened diagonally to this square piece of wood. Another wire, I H, of the same thickness, having a brass ball, H, screwed on its pointed extremity, is fastened upon the board A; so also is the wire M N, which is shaped in a ring at O. From the upper extremity of the glass pillar C D, a crooked wire proceeds, having a spring socket F, through which a double-knobbed wire slips perpendicularly, the lower knob G of which falls just above

above the knob H. The glass pillar D C must not be made very fast into the bottom board; but it must be fixed so as it may be pretty easily moved round its own axis, by which means the brass ball G may be brought nearer or farther from the ball H, without touching the part E F G. Now when the square piece of wood L M I K (which may represent the shutter of a window or the like) is fixed into the hole so, that the wire L K stands in the dotted representation I M, then the metallic communication from H to O, is complete, and the instrument represents a house furnished with a proper metallic Conductor; but if the square piece of wood L M I K is fixed so, that the wire L K stands in the direction L K, as represented in the figure, then the metallic Conductor H O, from the top of the house to its bottom, is interrupted at I M, in which case the house is not properly secured.

Fix the piece of wood L M I K, so that its wire may be as represented in the figure, in which case the metallic Conductor H O is discontinued. Let the ball G
be

be fixed at about half an inch perpendicular distance from the ball H, then, by turning the glass pillar D C, remove the former ball from the latter: by a wire or chain connect the wire E F with the wire Q of the jar P, and let another wire or chain, fastened to the hook O, touch the outside coating of the jar. Connect the wire Q with the prime Conductor, and charge the jar; then, by turning the glass pillar D C, let the ball G come gradually near the ball H, and when they are arrived sufficiently near one another, you will observe that the jar explodes, and the piece of wood, L M I K, is pushed out of the hole to a considerable distance from the thunder-house. Now the ball G, in this experiment, represents an electrified cloud; which, when it is arrived sufficiently near the top of the house A, the Electricity strikes it, and, as this house is not secured with a proper Conductor, the explosion breaks part of it, *i. e.* knocks off the piece of wood I M.

Repeat the experiment with only this variation, *viz.* that this piece of wood I M
is

is situated so, that the wire L K may stand in the situation I M; in which case the Conductor H O is not discontinued; and you will observe, that the explosion will have no effect upon the piece of wood L M; this remaining in the hole unmoved; which shows the usefulness of the metallic Conductor.

Further: Unscrew the brass ball H from the wire H I, so that this may remain pointed, and, with this difference only in the apparatus, repeat both the above experiments; and you will find that the piece of wood I M is in neither case moved from its place, nor any explosion will be heard; which not only demonstrates the preference of Conductors with pointed terminations to those with blunted ones, but also shows, that a house furnished with sharp terminations, although not furnished with a regular Conductor, is almost sufficiently guarded against the effects of lightning.

To prove farther the preference of pointed Conductors to blunt ones, the experiment of the electrified cotton (*viz.* the
fourth

fourth experiment of this chapter) may be easily repeated with this apparatus; by which it may be shown, that a pointed Conductor silently drawing off the electric fluid from the small clouds near it, which are represented by the cotton tied to the wire of the ball G, repels them, and may thus, in some cases, perhaps, actually prevent a stroke of lightning; whereas the blunted Conductor facilitates it. Small feathers may also be tied near the knob G, which, by repelling one another, may exhibit a better representation of an electrified cloud; and in short, with a little contrivance, the above-described apparatus, commonly called the *Thunder-house*, may be adapted to represent the principal phenomena of lightning, together with several circumstances preceding, or following it.

CHAP. X.

The practical Administration of Medical Electricity.

WHEN we mentioned the uses of Electricity, in the First Part of this Treatise, we observed that Electricity had been found beneficial in many disorders, occasioned by obstructions, in which a promotion of the insensible perspiration, and of glandular secretion, was necessary, or an additional impetus required to be given to the common course of the fluids in the human body. We also considered the different opinions relating to this subject. In this chapter, therefore, nothing remains but to describe a practical method of applying Electricity to the human body, when affected with different distempers.

With respect to the electrical machine in general, I shall only observe, that its size should not be so small as was thought sufficient some time ago, when the smallest machines were supposed to be sufficiently
useful

useful for the purpose. It is somewhat remarkable, that when a small power of Electricity is to be used, large machines should be recommended ; whereas, a short time ago, strong shocks were administered, and small electrical machines were used ; but it must be considered, that when shocks are given, very small electrical machines can charge a Leyden phial much stronger than required ; but when the stream is used, which has lately been found to be far more efficacious ; then the small machines are mostly useless. Probably the largest machines will not be found to afford a stream too strong for medical purposes ; but the useful ones, which do not require a great labour to be put in motion, and may furnish a sufficiently dense stream, should have the glass globe, or cylinder, at least nine inches in diameter ; which, with a proportionate conductor, may usually give sparks about three inches long. Whether the rubber of these machines stands upon a glass pillar or not ; *viz.* whether it may be occasionally insulated or not, seems to be immaterial with respect to medical Electricity : but as to have
it

it situated upon a glass pillar, is useful for electrical experiments in general ; and perhaps it may be found hereafter, that negative electrization is beneficial in some disorders, a person who is to choose a new electrical machine, may rather have the rubber fixed upon a glass pillar, than otherwise.

With such machines, the power of Electricity should be so regulated, as to apply every degree of it with facility and readiness ; beginning with a stream issuing out of a metal point, next using a wooden point, then small sparks, stronger sparks, and lastly, small shocks. Every one of these methods may be increased or diminished considerably, by a proper management : thus, by turning the wheel of the machine swifter or slower, the stream of electric fluid may be regulated according as the circumstances may require. The sparks may also be made stronger or weaker, by taking them at a greater or less distance, and by turning the wheel swifter or slower ; and so of the rest.

It is impossible to prescribe the exact degree of electrization that must be used for various disorders; for persons of different constitutions, although afflicted with the very same disease, require different degrees of electrization. Some persons are of so delicate and irritable constitution, that the smallest sparks give them as much pain as shocks do to others. On the contrary, some people can suffer pretty severe shocks without positive pain; and I have heard, though never saw any, of persons who were insensible of any electric power, even of considerably strong shocks.

In respect to this important point, the operator must be certainly instructed by experience; however, in the beginning, he may be assisted by the two following rules: First, he should begin to administer to his patients the very smallest degree of electric power, which he ought to continue for a few days, so as to observe whether it produces any good effect, which if it fails to do, he should then increase the strength of electricity; and so proceed gradually till he finds the effectual method, which he should follow without variation,

till the patient is intirely cured. In short, the operator should always use the smallest degree of electric power, that is sufficient for the purpose. A little practice will enable him to determine at once what degree of Electricity is required for his patient, without any useless attempts. Secondly, the degree of electrization to be administered, should never exceed that, which the patient can conveniently suffer; experience shewing, that when the application of any degree of Electricity is very disagreeable to the patients, they very seldom mend.

The instruments which, besides the electrical machine and its prime Conductor, are necessary for the administration of medical Electricity, may be reduced to three; *viz.* an electric jar, with Mr. LANE's electrometer; an insulated chair, or an insulated stool, upon which a common chair may be occasionally set; and the *directors* *.

* Various other instruments useful in medical Electricity, are described in divers books, but those mentioned above are sufficient to answer every required purpose.

As for the jar with Mr. LANE's electrometer, it has been already described, and is clearly shewn by fig. 6. of Plate II. We may only observe, that for medical Electricity this jar needs not be large; it being fully sufficient when it contains about 60 or 70 square inches of coated surface. The balls A B of the electrometer, at most should not be placed farther asunder than a quarter of an inch, but in general one tenth of an inch distance is sufficient.

When the shocks are to be given with this apparatus to any particular part of the body, for instance, to the arm, then, instead of the dotted line representing a wire, which must now be supposed as not existing in the figure, two slender and pliable wires, C H, K I, are to be fastened, one to the open ring C of the electrometer, and the other to the outside coating of the jar. The other extremities of the said wires are fastened each to the brass wire I, and H of the directors I L, H L. Each of those instruments, justly called *directors*, consists of a knobbed brass wire, which by means of a brass cap is cemented to the glass handle

handle L. The operator holding them by the extremity of the glass handle, brings their balls into contact with the extremities of that part of the body of the patient, through which he desires to send the shock. The management and convenience of this apparatus are easily comprehended; for when the machine is in motion, and the apparatus, &c. is situated as in the figure, the discharge of the jar must be evidently made through that part of the patient which lies between the knobs of the directors; and the operator, whilst an assistant keeps the machine in motion, has nothing more to do, but to hold the knobs of the directors to the extremities of the arm, or to any other part of the body that is required to be thus electrified; always taking care that the two wires K I, C H, do not touch each other, because in that case the shock will not pass through that part of the body which is required to be electrified. Thus any number of shocks, precisely of the same strength, may be given, without altering any part of the apparatus, or having any farther trouble; and when the strength of the shocks is required

to be diminished or increased, it is only necessary to diminish or augment the distance between the balls B C, which is done by slipping the wire C B forwards or backwards through the spring socket that holds it.

It is almost superfluous to mention, that when shocks are administered, it is immaterial whether the patient stands upon the ground, upon the insulating stool, or in any other situation whatever. It is neither always necessary to remove the cloaths from the part that must be electrified, in order to let the knobs of the directors touch the skin ; for except the coverings be too many and too thick, in which case part of them at least should be removed, the shocks will go through them very easily, especially if the knobs of the directors be pressed a little upon the part.

Besides the directors mentioned above, there are other kinds of directors, which serve for throwing the stream of electric fluid, and other similar purposes. These are much like those described above, excepting

cepting only that its wire is bent, and instead of having any ball, it terminates in a point, to which is affixed a piece of wood about one inch or one inch and a half long, pointed at one end, though not very sharp, and having a hole at the other. The operator should have by him various such wooden pieces, of different length and thickness, so as to shift them according as circumstances may require; for sometimes the wooden pieces are too dry or too damp, or the machine is in bad order, &c. in which cases the stream of electric fluid would be either too strong or too weak, if the same wooden point was always used. The wood proper to make these pointed pieces should be rather of a soft kind, than hard, as box wood and *lignum vitæ* are.

In order to throw the electric fluid with this director, let a wire proceeding from the prime Conductor be fastened to the wire of the director, which the operator must hold by the extremity of the glass handle, and must manage it so as to keep the wooden point at about one or two inches distance from the body of the pa-

tient*. This distance, however, must be regulated according to the constitution of the patient, the strength of the electrical machine, and other circumstances; which will be suggested by a little practice. The electric fluid issuing from the wooden point, has a power which is intermediate between that of the stream proceeding from a metal point, and the power of the sparks; but yet it is in general the most efficacious method of electrization, and therefore no pains should be spared in order to administer it in the best possible manner. This stream consists of a vast number of exceedingly small sparks, accompanied with a little wind, which gently irritates the part electrified, and gives a warmth which proves very agreeable to the patients. Sometimes, when the machine is very powerful, and the wooden point is short or split, a very full and pungent spark issues from it, which is a very disagreeable acci-

* When this or any other operation is performed, the electric jar, and in general any instrument not actually necessary, must be removed from the prime conductor, and even from the table if that is rather small.

dent,

dent, especially when the part electrified is very delicate. In order to avoid this inconvenience, the operator should first try the goodness of the point, before he begins the operation; which he may do by throwing the stream upon his own hand or face.

The above-mentioned method of electrifying, gentle as it may appear, will nevertheless be found too strong for some persons, especially when used for open sores upon delicate parts; in which cases the wooden point must be removed, and the electric fluid must be simply thrown from the metal point of the director, which must now be kept at a greater distance than when the wooden piece was upon it. The electric fluid issuing out of this pointed wire of the director, occasions only a gentle wind upon the part towards which it is directed, and is far from being disagreeable even to the most delicate constitution.

It might be naturally suspected, that so gentle and nearly insensible a treatment could hardly be of any efficacy; but my
reader

reader may be assured, that to my certain knowledge, deduced from the practice of persons who have had long experience in this subject, this method of electrization, *viz.* the throwing the fluid with a metal point, has often mitigated pains, and cured obstinate and dangerous diseases, which could not be removed by any other remedy that was tried.

In general, this treatment upon delicate nervous constitutions, is as efficacious as the other, *viz.* the throwing the fluid with a wooden point, is to ordinary constitutions. In several cases, especially of open sores, the electric fluid issuing out of a wooden point has constantly increased the pain, and even enlarged the sore; whereas the fluid issuing out of the metal point, has effectually diminished both.

The stream issuing out of a wooden point may be directed towards the eyes of the patient, without any apprehension of hurting him; in which case the operator should keep the eye-lid open with one hand. Indeed there may be some cases, though
I seldom

I seldom heard of any, in which this treatment may be thought to be too strong; then the metal point only may be used.

The stream issuing both out of the wooden and of the metal point, acts even through the cloaths, if they are not too thick; hence it may be used without incommoding the patient; but when it is convenient to uncover the part that is to be electrified, it is much preferable to direct the fluid immediately upon the skin.

In this operation, the practitioner must mind to shift the point of the director about, so that the stream of electric fluid may be directed not only towards the affected part, but also to the places about it; alternately returning to the same place, and mostly insisting upon the part principally affected.

The patient in this operation may also stand in every situation that may happen to be more convenient to him.

When

When more proper instruments cannot be had, directors may be made by sticking large pins upon sticks of sealing-wax.

In regard to the continuation of the operation in various cases, it is impossible to give any particular directions, since the variety of cases is almost infinite. The operator will be easily instructed by practice; but for the beginning he may observe, that when sparks are administered, a dozen of them is fully sufficient; but when the stream of electric fluid is used, the operation may be continued for about 3 or 4 minutes per day. — As for farther particulars relating to the subject of this chapter, I must refer my reader to my Essay on medical Electricity; the limits of this work not permitting me to insist longer upon it.

C H A P. XI.

Experiments with the electrical Battery.

THE force of accumulated Electricity, great as it appears by the experiments performed with a single coated jar, is very small when compared with that, which is produced by a number of jars connected together; and if the effects of a single jar are surprising, the prodigious force of a large battery is certainly astonishing. To observe that the metals, even the most purified platina, which resists the greatest efforts of chemic fire, are actually, and almost instantaneously rendered red-hot, and fused; to see animals destroyed; and to hear the loud report of a large electric battery, are things that always produce a kind of terror in the mind of an attentive observer. Experiments of this kind should be conducted with great caution, and the Operator ought to be attentive, not only to the business in hand, but also to the persons who may happen to be near him, prohibiting their touching, or even coming too
near

near any part of the apparatus ; for if a mistake in performing other experiments may be disagreeable, those in the discharge of a large battery may be attended with worse consequences.

When a battery is to be charged, instead of a large prime Conductor, a small one is much more convenient ; for, in this case, the dissipation of the Electricity is not so considerable. The quadrant electrometer, which shows the height of the charge in the battery, may be fixed either upon the prime Conductor, or upon the battery ; in which latter case, it should be placed upon a rod proceeding from the wires of the jars, and if the battery be very large, it should be elevated two or three feet above them.

The index of the electrometer in charging a large battery will seldom rise so high as 90° , because the machine cannot charge a battery so high in proportion, as a single jar. Its limit is often about 60° or 70° , more or less in proportion to the size of the battery, and the force of the machine.

EXPE-

EXPERIMENT I.

To melt Wires.

Connect with the hook, communicating with the outside coating of a battery, containing at least thirty square feet of coated surface, a wire, that is about one fiftieth part of an inch thick, and about two feet long; the other end of it must be fastened to one end of the discharging rod; this done, charge the battery, and then, by bringing the discharging rod near its wires, send the explosion through the small wire, which, by this means, will be made red-hot, and melted, so as to fall upon the floor in different glowing pieces. When a wire is melted in this manner, sparks are frequently seen at a considerable distance from it, which are red-hot particles of the metal, that by the violence of the explosion are scattered in all directions. If the force of the battery is very great, the wire will be intirely dispersed by the explosion, so that none of it can be afterwards found.

By

By repeating this experiment with wires of different metals, and the same force of explosion, it will be found that some metals are more readily fused than others, and some not at all affected; which shows the difference of their conducting power. If it be required to melt such particles of metals, that cannot easily be drawn in wires, as ores, grain gold, &c. they may be set in a train upon a piece of wax; this train may be inserted in the circuit, and an explosion may be sent through it, which, if it is sufficiently strong, will melt the metallic particles, as well as the wires: or, if the quantity to be tried be large enough, it may be confined in a small tube of glass.

In melting wires of a considerable length, it is often observed, that when the force of the explosion is just sufficient to render the wire red-hot, the redness begins first from one end of it, namely, that which communicates with the positive side of the battery, and from thence gradually proceeds to the other end. This is another ocular demonstration of the theory of a single electric fluid. Indeed the wire is not rendered red-hot

hot in one place before the other, because the electric fluid passes first through the former, and then through the latter, for that difference of time is by far too small to be observed; but, because the electric fluid loses some of its impetus, or velocity, in going through the wire; hence the part of the wire which the electric fluid enters, suffers the greatest effect of the shock, and, consequently, becomes red sooner, and in a greater degree.

If a wire is stretched by weights, and a shock is sent through it, which renders it just red-hot, the wire, after the explosion, will be found considerably lengthened; but if the wire is left loose, after a similar explosion it will be found shortened*. If a wire is melted upon a piece of glass, the glass, after the explosion, will be found marked with all the prismatic colours.

* This is a late observation of Mr. EDWARD NAIRNE. See the Phil. Transf. vol. LXX.

EXPERIMENT II.

To show that the electric Fluid prefers a short Passage through the Air, to a long one through good Conductors.

Bend a wire about five feet long in the form represented by fig. 11. Plate II. so that the parts A B may come within half an inch of one another; then connect the extremities of the wire with the hook of the battery, and the discharging-rod, as directed in the preceding experiment, and send the charge of a battery through it. On making the explosion, a spark will be seen between A and B, which shows that the electric fluid chooses rather a short passage through the air, than the long one through the wire. The charge, however, does not pass intirely through A and B, but part of it goes also through the wire; which may be proved by putting a slender wire between A and B; for, on making the discharge with only this addition in the apparatus, the small wire will be hardly made red-hot; whereas, if the large wire A D B be

be cut in D, so as to discontinue the circuit A D B, the small wire will be melted, and even exploded, by the same shock that before made it scarcely red-hot. In this manner (says Dr. PRIESTLEY, who is the inventor of this experiment) may the conducting power of different metals be tried, using metallic circuits of the same length and thickness, and observing the difference of the passage through the air in each.

EXPERIMENT III.

To make Globules of Metals.

Take a very slender wire, and put it in a glass tube, about one quarter of an inch in diameter; then send the charge of a battery through it, and the wire will be melted, and reduced into globules of different sizes, which are found sticking on the inside surface of the glass tube, and they may be easily separated from it at pleasure: these, upon examination, will all be found hollow, and are little more than a mere scoria of metal.

It must be observed, in making this experiment, that the charge of the battery must neither be too high nor too weak; for in the former case, the wire will be reduced into pieces exceedingly small, or rather exploded in smoke; and in the latter case, it will be imperfectly fused, so that its pieces will be large and irregular.

EXPERIMENT IV.

The Fairy Circles.

Fix upon each of the knobs D D of the universal discharger, fig. 5. Plate I. or upon the wires that support the knobs, if the knobs are removed, a flattish and smooth piece of metal, or semi-metal (watch-cases are very fit for this purpose) so that their surfaces may come so near each other, that the battery may be discharged through them; then connect one wire of the discharger with the outside of the battery, and the other wire, by the help of the discharging rod, with the inside of it, so as to make the discharge; which will occasion the spot and circles described in
the

the first part of this Treatise, upon the surface of each of the pieces of metal fixed upon the discharger.

These circles have hitherto been exhibited upon the surface of no other substances but metals; and they are found to be marked more distinctly upon such metals as melt with the least heat. The most beautiful of these rings are produced by a number of discharges from a large battery, every part of the apparatus remaining exactly in the same situation. If the pieces of metal receive the explosion in vacuo, the spot formed on them is very irregular and confused.

I have given these spots the appellation of *Fairy Circles*, on account that they bear some resemblance to the spots so called, which are often observed upon the grass in the fields. These, which we may call natural Fairy Circles in the fields, have been thought to be effected by lightning, on account of their bearing some resemblance to the above-mentioned circles produced by Electricity; the supposition,

however, seems not very probable; for the spots in the fields, called Fairy Circles, have no central spot, no concentric circles, neither are they always of a circular figure; and, as I am informed, they seem to be rather beds of mushrooms than the effects of lightning.

EXPERIMENT V.

To mark coloured Rings on Metals.

In order to exhibit coloured rings upon the surface of metals, place a plain piece of any of the metals upon one of the wires of the universal discharger, and upon the other wire fix a sharp-pointed needle, with the point just opposite to the surface of the metal; then connect one wire of the discharger with the outside of a battery, and the other with the discharging-rod, &c. In this manner, if explosions are repeatedly sent either from the point to the piece of metal, or from the latter to the former, they will gradually mark the surface of the piece of metal opposite to the point with circles, consisting of all the
prismatic

prismatic colours; which are evidently occasioned by laminæ of the metal, raised by the force of the explosions.

These colours appear sooner, and the rings are closer to one another, when the point is nearer to the surface of the metal. The number of rings is greater or less, according as the point of the needle is more sharp or more blunt; and they are represented equally well upon any of the metals.

The point of the needle is also coloured to a considerable distance; the colours upon it returning in circles, though not very distinctly. This is an experiment of Dr. PRIESTLEY.

EXPERIMENT VI.

The imitation of an Earthquake.

The appearance of the earthquake, as represented with the explosion of a battery, is occasioned by the concussion given to several substances by the explosion

passing over their surfaces. To give a representation of the impression made upon houses by the earthquake, small sticks, cards, or the like, may be placed upon the surface of the body over which the explosion is to be transmitted, so as to stand very light. These sticks, &c. will never fail to be shook, and often be thrown down by the explosion.

It is remarkable, that an explosion will not pass over the same length of surface of all bodies, though they are equally good Conductors. Water, ice, wet wood, raw flesh, and most of the animal fluids, are the best to make this remarkable experiment; to do which, nothing more is required than to insert part of the surface of the said substances into the circuit of the two sides of a battery; a chain, for instance, communicating with the outside, may be placed so as nearly to touch the surface of a quantity of water, and at about eight or nine inches distant * from another

* The distance at which an explosion will strike over the surface of the above-mentioned substances, is much greater than that it can strike through in air only.

chain,

chain, situated also very near the surface of the water, and communicating with one end of the discharging-rod. If the ends of the chains touch the water, the experiment will happen in the same manner.

The report, in this experiment, is much louder than when the explosion passes through the air only. The concussion given to the water, by the explosion passing over its surface, is not only superficial, but affects its whole body; and if the hand is kept deep under its surface whilst the explosion passes over it, the concussion may be very sensibly felt.

The spark, that in this experiment passes over the surface of the water, seems to bear a great resemblance to the balls of fire that have sometimes been seen over the surface of the sea or land in time of an earthquake; and hence it seems very probable, that those balls of fire are electrical phenomena.

C H A P. XII.

Promiscuous Experiments.

E X P E R I M E N T I.

To show that Smoke, and the Vapour of hot Water, are Conductors.

LET a cork-ball electrometer be suspended about four or five feet above the prime Conductor, then turn the winch of the machine very gently, and you will find, that the balls of the electrometer will not diverge. Put upon the prime Conductor a wax-taper * just blown out, so that its smoke may ascend to the electrometer; then turn the winch again, and the balls of the electrometer will immediately separate a little, with the same force of Electricity, from the prime Conductor; which shows that smoke is a Conductor in a small degree.

* A green wax-taper is the best for this experiment.

In the same manner, by placing a small vessel with hot water upon the prime Conductor, instead of the wax-taper, it may be proved, that its vapour is also a Conductor; but inferior in its conducting power to the smoke. This experiment is an invention of Mr. HENLY.

EXPERIMENT II.

To prove that Glass, and other Electrics, become Conductors, when they are made very hot.

Take a small glass tube of about one twentieth of an inch in diameter, and above a foot long; close it at one end, and introduce a wire into it, so that it may be extended through its whole length: let two or three inches of this wire project above the open end of the tube, and there fasten it with a bit of cork; tie round the closed end of the tube another wire, which will be separated from the wire within the tube only by the glass interposed between them. In these circumstances endeavour to send a shock through the two wires;

i. e.

i. e. the wire inserted in the glass tube, and that tied on its outside, by connecting one of them with the outside, and touching the other with the knob of a charged jar, and you will find that the discharge cannot be made, unless the tube be broken; because the circuit is interrupted by the glass at the end of the tube which is interposed between the two wires. But put that end of the tube to which the wire is tied into the fire, so that it may become just red-hot, then endeavour to discharge the jar again through the wires, and you will find that the explosion will be easily transmitted from wire to wire, through the substance of the glass, which, by being made red-hot, is become a Conductor.

In order to ascertain the conducting quality of hot resinous substances, oils, &c. bend a glass tube in the form of an arch *C E F D*, fig. 7. Plate II. and tie a silk string *G C D* to it, which serves to hold it by when it is to be set near the fire; fill the middle part of this tube with rosin, sealing-wax, &c. then introduce two wires *A E*, *B F* through its ends, so that they
may

may touch the rosin, or penetrate a little way in it. This done, let a person hold the tube over a clear fire, so as to melt the rosin within it; at the same time, by connecting one of the wires, A or B, with the outside of a charged jar, and touching the other with the knob of the jar, endeavour to make the discharge through the rosin, and you will observe that, while the rosin is cold, no shocks can be transmitted through it; but it becomes a Conductor according as it melts, and when totally melted, the shocks will pass through it very freely.

EXPERIMENT III.

To show that hot Air is a Conductor.

Electrify one of the cork-ball electrometers, suspended upon the stand, fig. 4. of Plate I. or electrify the prime Conductor with the quadrant electrometer; then bring a red-hot iron within a sufficient distance of the electrometer, or prime Conductor, and you will find that they soon lose their Electricity, which is certainly

tainly conducted by the hot air contiguous to the iron ; for if the experiment be repeated with the same iron when cold, *i. e.* by bringing it within the same distance of the electrified Electrometer, or prime Conductor, their Electricity will not be conducted away as before *.

The above experiments may reasonably induce us to suspect, that several substances which are ranged among Conductors, would become Electrics, if they were brought into a cold temperature ; and that all the Electrics become Conductors, when they are heated in a very high degree.

* It has been often observed, that a battery may be discharged, by introducing a red-hot iron between two knobs interposed, and standing at some distance from each other in the circuit ; but if, instead of iron, there be introduced a piece of red-hot glass between the knobs (the distance between them remaining as at first) the battery cannot be discharged : whence we may infer, that either hot air is not so good a Conductor as has been imagined, or else, that air heated by iron (perhaps from its ignited particles) is stronger, with respect to its conducting power, than when heated by the red-hot glass.

EXPERIMENT

EXPERIMENT IV.

To electrify the Air of a Room.

The air surrounding the electrical machine when in use, and contiguous to every highly-electrified body, always acquires a portion of Electricity, which it retains for a considerable time, and which, in some measure, counteracts the Electricity of electrified bodies *. A very expeditious method, however, to electrify the air, is to fix two or three needles upon the prime Conductor, and to keep it strongly electrified for about ten minutes. If afterwards an electrometer be brought into the air surrounding the apparatus, it will plainly show, that the air has acquired a considerable quantity of Electricity, which it will retain even after the apparatus has been removed into another room. To

* An electrometer suspended to the prime Conductor, will diverge most after a few turns of the wheel; but afterwards the divergence will lessen, according as the air about the apparatus becomes electrified.

electrify

electrify the air negatively, connect the pointed needles with the rubber when insulated; and make a communication by a chain, or wire, from the prime Conductor to the table.

Another method of electrifying the air is, to charge a large jar, and insulate it: then connect a sharp-pointed wire, or a number of them, with the knob of the jar; and make a communication from the outside coating to the table. If the jar be charged positively, the air of the room will soon become strongly electrified positively likewise; but if the jar be charged negatively, the air will become also negative. A charged jar being held in one hand, and the flame of a candle, insulated, and held in the other, being brought near the knob of the jar, will also soon produce the same effect.

EXPERIMENT

EXPERIMENT V.

The Atmosphere of Smoke.

Take a brass ball, or any piece of metal that is free from points or edges, of about three or four inches diameter, and insulate it upon a narrow electric stand; then give it a spark with the knob of a charged phial, and immediately present to it a wax-taper just blown out and smoking. The smoke, in this case, will be attracted by the electrified body, and, by encompassing that body, will form a kind of atmosphere about it. This atmosphere will remain for a few seconds, and afterwards, beginning from the bottom, will gradually vanish, until at last, entirely departing from the electrified body, it goes off in a slender column, that soon rarefies, and diffuses itself into a considerable space.

This experiment will not succeed, unless it be made in very dry weather, and in a room where the air is not agitated. Care

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must

must also be taken, that, in blowing out the taper, and presenting it to the electrified body, the air be disturbed as little as possible.

This phenomenon has induced some philosophers to suppose, that the Electricity of an electrified body resided about it, *i. e.* rested upon its surface like an atmosphere; which, they thought, was made very evident by the smoke. But this appearance, when duly considered, is far from proving any such electric atmosphere; and the cause of it may be very easily explained in the following manner:—The smoke is attracted by the electrified body in the same manner, and for the same reason, that other bodies are attracted by it. It remains suspended about that body, and cannot all come into contact with its surface, on account of the elasticity of its particles. It remains so long suspended about the electrified body, and is not immediately repelled, because it is a bad Conductor, and acquires Electricity very slowly; but, having acquired a sufficient quantity of Electricity, it begins to
quit

quit the electrified body, and, ascending in the air, extends itself into a large space, in consequence of the repulsion existing between its own electrified particles.

EXPERIMENT VI.

To shew that Metals conduct the electric Fluid through their Substance.

Take a wire of any kind of metal, and cover part of it with some electric substance, as rosin, sealing-wax, &c. then discharge a jar through it, and it will be found, that it conducts as well with as without the electric coating. This proves that the electric fluid passes through the substance of the metal, and not over its surface. A wire continued through a vacuum, is also a convincing proof of the truth of this observation.

EXPERIMENT VII.

The electrified Cup and Chain.

Insulate a metallic cup, or any other concave piece of metal, and place within it a pretty long metallic chain, having a silk thread tied to one of its ends. To the handle of the cup, or to a wire proceeding from it, suspend a cork-ball electrometer; then electrify the cup, by giving it a spark with the knob of a charged phial, and the balls of the electrometer will immediately diverge. If, in this situation, one end of the chain be gradually raised up above the top of the cup, &c. by the silk thread, while the lower end of the chain remains in it, the balls of the electrometer will converge a little, and more or less in proportion to the elevation of the chain above the top of the vessel; which proves that the Electricity of the cup and chain together is more dense when these bodies are in a compact, than when they are in a more extended form. A more easy method to
shew

shew this property of Electricity, is that used by T. RONAYNE, Esq; which is as follows:— He excites a long slip of white flannel, or a silk ribband, by rubbing it with his fingers; then, by applying his hand to it, takes off as many sparks as the excited electric will give; but when the flannel, &c. has lost the power of giving any more sparks in this manner, he doubles, or rolls it up; by which operation the contracted flannel, &c. appears so strongly electrical, that it not only gives sparks to the hand brought near, but it throws out spontaneous brushes of light, which appear very beautiful in the dark.

EXPERIMENT VIII.

*To show the Course of the electric Fluid by the
Flame of a Wax-taper.*

Fix at that extremity of the prime Conductor which is the remotest from the machine, a brass rod six inches long, having on its extremity a brass ball about three-fourths of an inch in diameter, and let the winch of the machine be moved.

If in this situation the flame of a wax-taper be presented to the above-mentioned brass ball, it will be blown almost horizontally, and in a direction from the ball; that is, in the direction of the electric fluid. If a wire, with a like ball, be fixed to the insulated rubber, the flame of a wax-taper, presented to this ball, will be blown also in the direction of the electric fluid; that is, it will be blown upon the ball, showing the true course of the electric fluid in a very simple and convincing manner.

EXPERIMENT IX.

*To show the electric Attraction, and Repulsion
by the electric Light.*

Fix a pointed wire upon the prime Conductor with the point outward, and another like wire upon the insulated rubber; then let the winch of the machine be turned, and the points of both wires will appear illuminated, *viz.* the former with a brush, and the latter with a star. In this situation, take an excited glass tube, and bring it
it

it sideway of the point of the wire fixed upon the prime Conductor, and you will see that the brush of rays issuing from the point, is turned sideway, *i. e.* is repelled by the atmosphere of the tube; and if the excited tube be held just opposite to the point, the brush will entirely vanish, because both the tube and the point are electrified positively. If the excited tube be brought near the point of the wire fixed upon the rubber, the star upon it will turn itself towards the tube; for this wire, being electrified negatively, will attract the electric fluid of the excited tube.

If this experiment be repeated with an excited stick of sealing-wax, or any other electric negatively electrified, instead of the glass tube, it will be found that the brush proceeding from the wire fixed upon the prime Conductor, will turn itself towards the excited wax, &c. and the star upon the point of the wire negatively electrified, will be diverted from it, or entirely suppressed, if the excited stick of sealing-wax be brought just opposite to the point.

EXPERIMENT X.

The electrified Capillary Syphon.

Let a small bucket of metal, full of water, be suspended from the prime Conductor, and put in it a glass syphon of so narrow extremity, as the water will just drop from it. If in this disposition of the apparatus the winch of the machine be turned, the water, which, when not electrified, only dropt from the extremity of the syphon, will now run in a full stream, which will even be subdivided into other smaller streams ; and if the experiment be made in the dark, it will appear beautifully illuminated.

EXPERIMENT XI.

The electrified Bells.

Fig. 10 of Plate II. represents an instrument having three bells, which are caused to ring by the power of electric attraction and repulsion. B is a brass piece furnished
with

with a hook, by which it may be suspended from the rod proceeding from the extremity of the prime Conductor A. The two bells C, and E are suspended by brass chains; but the middle bell D, and the two small brass clappers between C D, and D E, are suspended by silk threads. From the concave part of the bell D a brass chain proceeds, which falls upon the table, and has a silk thread F at its extremity. The apparatus being disposed as in the figure, if the cylinder of the machine be turned, the clappers will fly from bell to bell with a very quick motion, and the bells will ring as long as they are kept electrified.

The two bells C and E, being suspended by brass chains, are first electrified, hence they attract the clappers, communicate to them a little Electricity, and repel them to the unelectrified bell D, upon which the clappers deposit their Electricity, and then run again to the bells C E, from which they acquire more Electricity, &c. If by holding the silk thread F, the chain of the middle bell be raised from the table, the bells, after ringing a little while, will stop, because

because the bell D remaining insulated, will soon become as strongly electrified as either of the other two bells, in which case the clappers, having no opportunity to deposit the Electricity that they acquire from the bells C, E, must consequently stop.

If this experiment be made in the dark, sparks will be seen between the clappers and the bells.

EXPERIMENT XII.

The Spider seemingly animated by Electricity.

Fig. 9 of Plate II. represents an electric jar, having a wire C D E fastened on its outside, which is bended so as to have its knob E, as high as the knob A. B is a spider made of cork, with a few short threads run through it, to represent its legs. This spider is fastened at the end of a silk thread, proceeding from the ceiling of the room, or from any other support, so that the spider may hang mid-way between the two knobs A, E, when the jar is not charged.

charged. Let the place of the jar upon the table be marked; then charge the jar by bringing its knob A in contact with the prime Conductor, and replace it in its marked place. The spider will now begin to move from knob to knob, and continue this motion for a considerable time, sometimes for several hours.

The inside of the jar being charged positively, the spider is attracted by the knob A, which communicates to it a small quantity of Electricity; the spider then becoming possessed of the same Electricity with the knob A, is repelled by it, and runs to the knob E, where it discharges its Electricity, and is then again attracted by the knob A, and so on. In this manner the jar is gradually discharged; and when the discharge is nearly compleated, the spider finishes its motion.

EXPERIMENT XIII.

The Spiral Tube.

Fig. 13 of Plate II. represents an instrument composed of two glass tubes C D,
one

one within another, and closed with two knobbed brass caps A, and B. The innermost of these tubes has a spiral row of small round pieces of tin-foil, stuck upon its outside surface, and laying at about one thirtieth of an inch from each other. If this instrument be held by one of its extremities, and its other extremity be presented to the prime Conductor, every spark that it receives from the prime Conductor, will cause small sparks to appear between all the round pieces of tin-foil stuck upon the innermost tube, which in the dark affords a pleasing spectacle; the instrument appearing encompassed by a spiral line of fire.

The small round pieces of tin-foil are sometimes stuck upon a flat piece of glass, A B C D, fig. 12, so as to represent curve lines, flowers, letters, &c. and they are illuminated after the same manner as the spiral tube; *i. e.* by holding the extremity C, or B in the hand, and presenting the other extremity to the prime Conductor, when the machine is in motion.

EXPE-

EXPERIMENT XIV.

The dancing Balls.

Fix a pointed wire upon the prime Conductor, with the point outward; then take a glass tumbler, grasp it with your hands, and present its inside surface to the point of the wire upon the prime Conductor, while the machine is in motion; the glass in this manner will soon become charged; for its inside surface acquires the Electricity from the point, and its outside loses its natural quantity of electric fluid through the hands, which serve as a coating. — This done, put a few pith-balls upon the table, and cover them with this charged glass tumbler. The balls will immediately begin to leap up along the sides of the glass, as represented fig. 15, Plate II. and will continue their motion for a considerable time.

In this experiment the pith-balls are attracted and repelled by the electric fluid superinduced upon the inside surface of the glass,

glass, which they gradually conduct to the table or other conducting body upon which the glass is set; at the same time that the outward surface of the glass acquires the electric fluid from the contiguous air.

C H A P. XIII.

Further Properties of the Leyden Phial, or charged Electrics.

TH E properties of charged electrics, plain as they may appear at first sight, and conformable to the commonly-established theory of Electricity, are yet, when attentively considered, far from being intirely understood, so as to require no further experiments, or leave no doubt in the mind of the speculative Electrician. The first question, that naturally occurs, in considering a charged phial, is, Where does the superinduced electric fluid reside? — Is it lodged in the substance of the glass, or in the air contiguous to the surface of the phial? In the first case, if the electric fluid penetrates a certain quantity
of

of the substance of the glass, it follows, that a glass plate may be given so thin, that the electric fluid may freely pervade its substance *. If such a plate can be made, it will be easy, from thence, to determine how far the electric fluid can penetrate the substance of the glass, when charged in the usual manner. In the second case, if the electric fluid resides in the air contiguous to the glass, it must repel that air, *i. e.* a glass bottle should contain less air when charged, than when in its natural state; but this is contrary to experience.

The late Mr. CANTON charged some thin glass balls of about an inch and a half in diameter, having tubes of about nine inches in length, and afterwards sealed them hermetically. If these balls, when they were cold, were presented to an electrometer, they shewed no sign of Electricity; but if they were kept a little while

* I have often blown glass balls so thin, that their thickness was less than one six-hundredth part of an inch, and have always observed, that they were capable of receiving a charge, which they retained for a considerable time, if they were not made very hot.

near the fire, they then appeared strongly electrical, and possessed of that kind of Electricity with which their inside had been charged. Mr. CANTON discovered farther, that if these balls are kept under water, they retain their virtue for a considerable time, even for several years; but if they are often used, their power is soon exhausted. It is obvious to remark, that the Electricity, which appears upon the outside of these balls, when they are rendered hot, *i. e.* when the glass is rendered a Conductor by the heat, is not that Electricity, which properly constitutes the charge, but the superfluous Electricity of their inside*.

* If a charged jar be insulated, and discharged with an insulated discharging rod, after the discharge both the sides of the jar, together with the discharging rod, will be found possessed of the Electricity contrary to the Electricity of that side of the jar, which was touched last before the discharge; which shows that one side of a charged electric may contain a greater quantity of Electricity than that, which is sufficient to balance the contrary Electricity of the opposite side. This redundant Electricity should be carefully considered in performing experiments of a delicate nature.

As

As for the Electricity, which constitutes the charge, it being just sufficient to balance the contrary Electricity of the opposite surface of the glass, it will lose its power as soon as it is arrived to that surface, which in the case of the above-mentioned balls, it actually reaches, before it can act upon the electrometer.

The most remarkable phenomena produced by charged electrics, are exhibited with flat plates of glass, jointly charged, like a single coated plate. If two glass plates, having plain surfaces, be placed one upon the other, and their outward surfaces be coated with tin-foil, in the usual manner of coating a single plate for the Leyden experiment, and then be charged, by presenting one coating to the prime Conductor, and communicating the other with the earth, the plates (which we shall call A, and B) after having been charged, will adhere very firmly to one another, and if separated, A, *viz.* that, whose coating was presented to the prime Conductor, will appear positive on both sides, and B negative on both sides. If these plates are laid in contact

A a

tact

tact as before they were charged, and are discharged by making a communication between the two coated sides, they will be found still to adhere to one another after the discharge; and if separated, they will appear still electrified, but with this remarkable difference, *viz.* that now A is negative on both sides, and B positive on both sides. If these plates, after being discharged, be separated in the dark, flashes of light are perceivable between their internal surfaces. By laying the plates together, touching their coatings, and separating them successively, the flashes may be observed for a considerable number of times, diminishing by degrees, until they quite vanish.

Father BECCARIA explains these, and other similar phenomena of charged as well as of excited electrics, by the following principle, which he distinguishes by the name of *vindicating Electricity*. When two bodies, either a Conductor and an electrified electric, or two contrarily and equally electrified electrics, are joined together, they adhere to each other, and their

Electricities

Electricities disappear; but as soon as they are separated, the electrics recover their Electricities *. How far this principle can be of use to explain the phenomena of charged glass, &c. I will not take upon me to determine. It would exceed too far the limits of my work, if I were to enumerate and account for all the particulars. When the principle is expressed, the ingenious reader may easily apply it to explain the effects. I shall only mention an observation of Mr. HENLY, relative to this subject, which seems not conformable to Father BECCARIA's theory; and with that I shall conclude this Part of my work. Says Mr. HENLY, in one of his papers presented to the Royal Society, in which he describes the above mentioned experiments of the two glass plates: — “ Crown-glass, “ that is, the glass commonly used for “ sash-windows, though so much thinner, “ succeeds in this experiment as well as “ the plate-glass; but what is very remarkable, the Dutch plates, when treated in the same manner, have each a po-

* See BECCARIA's Artificial Electricity, Part II. Sec. VI.

“ fitive and negative surface, and the Elec-
 “ tricity of both surfaces of both plates
 “ is exchanged for the contrary Electri-
 “ city in the discharge. If a clean, dry,
 “ uncoated plate of looking-glass be
 “ placed between the coated looking-glass
 “ plates, or between the plates of crown-
 “ glass, it appears, after charging, to be
 “ negatively electrified on both sides; but
 “ if it be placed between the Dutch
 “ plates, it acquires, like them, a positive
 “ Electricity on one surface, and a nega-
 “ tive Electricity on the other.”

In another paper Mr. HENLY further
 observes, that if the Dutch plates are se-
 parated immediately after being charged,
 they will then act like two plates of look-
 ing-glass, *i. e.* one of them will be positive,
 and the other negative on both sides; but if
 a little time be allowed before the plates be
 separated, the experiment will constantly
 succeed as above *.

* To this second edition, a dissertation on the *vin-
 dicating Electricity* has been added in the Appendix;
 which will shew, by plain experiments, this wonder-
 ful property of glass, &c. whilst this chapter has been
 here reprinted just as it was published in the first
 edition.

P A R T

P A R T IV.

NEW EXPERIMENTS IN ELECTRICITY.

THE laws of Electricity, together with the experiments necessary for their demonstration, having already been described, in as compendious a manner as could be done without obscurity, I shall, in the last Part of this Work, relate such new experiments and observations as I have made during the course of about two years; in which time I have pursued the Science of Electricity, with a particular view to discover, if possible, the unknown cause of several electrical phenomena, especially those relative to atmospherical Electricity.

The first instrument that I made use of to observe the Electricity of the atmosphere, was an electrical kite, which I had constructed, not with a view to observe the Electricity of the air; for this, I thought,

was very weak, and seldom to be observed; but as an instrument which could be occasionally used in time of a thunder-storm, in order to observe the Electricity of the clouds. The kite, however, being just finished, together with its string, which contained a brass wire through its whole length, I raised it the 31st of August 1775, at seven of the clock in the afternoon, the weather being a little cloudy, and the wind just sufficient for the purpose. The extremity of the string being insulated, I applied my fingers to it; which, contrary to my expectation, drew very vivid and pungent sparks: I charged a coated phial at the string several times; but I did not then observe the quality of the Electricity. This successful experiment induced me to raise the kite very often, and to keep it up for several hours together; thinking that if any periodical Electricity, or any change of its quality took place in the atmosphere, it might very probably be discovered by this instrument. In the following two Chapters I shall describe the construction of the electrical kite, with its appurtenances; and shall transcribe the most remarkable

markable part of my journal relative to the kite; *i. e.* describing such experiments only which are most remarkable, and do not happen very commonly; for although I have used my kite sometimes ten, and more times in a week, and at any hour of the day or night, yet as the greatest part of those experiments are only of use to confirm a few laws of atmospherical Electricity, I shall leave their particular detail, and shall only subjoin those laws at the end of the second chapter.

C H A P. I.

The Construction of the electrical Kite, and other Instruments used with it.

TH E first electrical kite that I constructed, was seven feet high; and it was made of paper, with a stick or straiter, and a cane-bow, like the kites commonly used by school-boys. On the upper part

of the straiter I fixed an iron spike, projecting about a foot above the kite, which I then thought was absolutely necessary to collect the Electricity; and I covered the paper of the kite with turpentine, in order to defend it from the rain. This kite, perfect as I thought it to be in its construction, and fit for the experiments for which it was intended, soon manifested its imperfections, and, after being raised a few times, it became quite unfit for farther use; it being so large, and consequently heavy, that it could not be used, except when the wind was strong; and then, after much trouble in raising and drawing it in, it often received some damage: which soon obliged me to construct other kites upon a different plan, in order to ascertain which method would answer the best for my purpose. I gradually lessened their size, and varied their form, till I observed upon trial, that a common school-boy's kite was as good an electrical kite as mine. In consequence of which, I constructed my kites in the most simple manner, and in nothing different from the children's kites, except

except that I covered them with varnish, or with well-boiled linseed-oil, in order to defend them from the rain ; and I covered the back part of the straiter with tin-foil, which, however, has not the least power to increase its Electricity. I also furnish the upper extremity of the straiter with a slender wire pointed, which, in time of a thunder-storm, may perhaps draw the Electricity from the clouds somewhat more effectually ; but in general, I find, as it will appear in the account of the experiments, that it does not in the least affect the Electricity at the string. The kites that I generally have used are about four feet high, and little above two feet wide. This size, I find, is the most convenient, because it renders them easy to be managed, and, at the same time, they can draw a sufficient quantity of string. As for silk or linen kites, they require a good deal of wind to be raised ; and then they are not so cheap, nor so easy to be made, as paper kites are. The string sometimes breaks, and the kite is lost, or broken ; for which reason these kites should be
made

made as cheap and as simple as possible.

The string is the most material part of this apparatus; for the Electricity produced is more or less, according as the string is a better or a worse Conductor. The string which I made for my large kite, consisted of two threads of common twine, twisted together with a brass wire between the strands. This string served very well for two or three trials, but, on examination, I soon found, that the wire in it was broken in many places, and it was continually snapping; the metallic continuation, therefore, being so often interrupted, the string became soon so bad, that it acted nothing better than common twine without a wire. I attempted to mend it, by joining the broken pieces of wire, and working into the twine another wire, which proved a very laborious work; but the remedy had very little effect; the wire breaking again after the first trial: which determined me to adopt other methods; and, after several experiments,

ments, I found that the best string was one, which I made by twisting a copper thread * with two very thin threads of twine. Strings like this I have used for the greatest part of my experiments with the kite, and I find them to be exceedingly useful, and fit for the purpose. Silver or gold thread would do much better to twist with the twine, because they are much thinner than copper thread, and, in consequence, the string would be much lighter; but, at the same time, it is to be considered, that gold or silver thread is much dearer than copper thread.

I have attempted to render the twine a good Conductor of Electricity, by covering it with conducting substances; as lamp-black, powder of charcoal, very fine emery, and other substances, mixing them with diluted gum-water; but this method improves the string very little, and for a

* I mean such a thread of copper as is used for trimmings, &c. in imitation of gold threads; which are nothing more than silk, or linen threads, covered with a thin lamina of copper.

very short time; for the said conducting substances are soon rubbed off the twine. Mr. NAIRNE informed me, that he had used to soak the string of his electrical kite in a strong solution of salt, which rendered it a good Conductor, so far as it attracted the moisture of the air. In consequence of this information, I soaked in salt-water a long piece of twine, and, by raising a kite with it, I found that it conducted the Electricity pretty well; but I thought it much inferior to the above-described string with the copper thread: besides, the salted string in wet weather not only leaves part of the salt upon the hands of the operator, and, in consequence, renders them unfit to manage the rest of the apparatus, but it marks a white spot wherever it touches the clothes.

In raising the kite when the weather is very cloudy and rainy, in which time there is fear of meeting with great quantity of Electricity, I generally use to hang upon the string A B, fig. 8. Plate II. the hook of a chain C, the other extremity of which falls upon the ground. Sometimes

I use another caution besides, which is, to stand upon an insulating stool; in which situation I think, that if any great quantity of Electricity, suddenly discharged by the clouds, strikes the kite, it cannot affect much my person. As to insulated reels, and such-like instruments, that some gentlemen have used to raise the kite, without danger of receiving any shock; fit for the purpose as they may appear to be in theory, they are yet very inconvenient to be managed. Except the kite be raised in time of a thunder-storm, there is no great danger for the operator to receive any shock. Although I have raised my electrical kite hundreds of times without any caution whatever, I have very seldom received a few exceedingly slight shocks in my arms. In time of a thunder-storm, if the kite has not been raised before, I would not advise a person to raise it while the stormy clouds are just overhead; the danger in such time being very great, even with the precautions above-mentioned: at that time, without raising the kite, the Electricity of the clouds may be observed by a cork-ball electrometer held in the
hand

hand in an open place, or if it rains, by my electrometer for the rain ; which will be described hereafter.

When the kite has been raised, I generally introduce the string through a window in a room of the house, and fasten it to a strong silk lace, the extremity of which is generally tied to a heavy chair in the room. In fig. 8. of Plate III. A B represents part of the string of the kite which comes within the room ; C represents the silk lace ; D E, a small prime Conductor, which, by means of a small wire, is connected with the string of the kite ; and F represents the quadrant electrometer, fixed upon a stand of glass covered with sealing-wax, which I used to put near the prime Conductor, rather than to fix it in a hole upon the Conductor, because the string A B sometimes shakes so as to pull the prime Conductor down ; in which case the quadrant electrometer remains safe upon the table, otherwise it would be broken, as I have often experienced before I thought of this method. G represents a glass tube, about eighteen inches long, with a knobbed wire cemented

mented to its extremity ; which instrument I use to observe the quality of the Electricity, when the Electricity of the kite is so strong that I think it not safe to come very near the string. The method is as follows : — I hold the instrument by that extremity of the glass tube which is the farthest from the wire, and touch the string of the kite with the knob of its wire, which, being insulated, acquires a small quantity of Electricity from it ; which is sufficient to ascertain its quality when the knob of the instrument is brought near an electrified electrometer. Sometimes, when I raise the kite in the night-time, out of the house, and where I have not the convenience of observing the quality of its Electricity by the attraction and repulsion, or even by the appearance of the electric light, I make use of a coated phial, which I can charge at the string, and, when charged, put into my pocket ; wherein it will keep charged even for several hours *. By making use of this instrument,

* The construction of this phial is as follows : — Besides the coating on the inside and outside, that this phial has, like any other of the same kind, a glass tube,

strument, I am obliged to keep the kite up no longer than is necessary to charge the phial, in order to observe the quality of the Electricity in the atmosphere; for after the kite has been drawn in and brought home, I can then examine the Electricity of the inside of the phial, which is the same as that of the kite.

tube, open at both ends, is cemented into its neck, and proceeds within the phial, having a small wire fastened to its lower extremity, which touches the inside non-electric coating. The wire with the knob of this phial is cemented into another glass tube, which is nearly twice as long, and smaller than the tube cemented into the neck of the phial. The wire is cemented so, that only its knob projects out of one end, and a small length of it out of the other end of the tube. If this piece with the wire be held by the middle of the glass tube, it may be put in or out of the tube which is in the neck of the phial, so as to touch the small wire at the lower extremity of it, and that without discharging the phial, if it is charged. I have kept such a phial charged for six weeks together; and probably it would keep much longer, if it were to be tried. The ingenious young Electrician may make use of such a phial for several diverting purposes. — The piece of glass which serves to hold the wire by, is rather better to be fixed above than below the ball. In this case, the ball is perforated quite through, and the wire projects a short way above it; to which the glass tube is cemented.

When

When the Electricity of the kite is very strong, I fix a chain, communicating with the ground, at about six inches distance from the string; which may carry off its Electricity, in case that this should increase so much as to put the by-standers in danger.

Besides the above-described apparatus, I have occasionally used some other instruments, which I have often varied, according as some particular experiments required; but, as they are of no great consequence, I shall omit to describe them. It is only necessary, before I enter into the narration of the principal experiments performed with the kite, to give an idea of the standard of my quadrant electrometer; which may, very probably, shew the same intensity of Electricity under a number of degrees different from the other instrument of the same kind. When the kite is flying, and the apparatus is disposed as in fig. 8. of Plate III. I bring, under the extremity E of the prime Conductor, a little bran, held upon a tin plate, and observe, that when the index of the electrometer is at ten degrees, the

B b

prime

prime Conductor begins to attract the bran at the distance of about three-fifths of an inch ; when the index is at twenty degrees, the prime Conductor attracts the bran at the distance of about one inch and a quarter ; when the index is at thirty degrees, the bran begins to be attracted at the distance of two inches and one-fifth. These distances vary, as the weather changes its degree of dryness ; but in frosty weather I observe them constantly as above.

C H A P. II.

Experiments performed with the electrical Kite.

September the 2d, 1775. The weather being very cloudy, and actually raining, the kite was raised at eight o'clock P. M. with two hundred yards of string, which had a brass wire through its whole length. The wind was from the south and very strong. The Electricity at the string was negative, and just sufficient to charge a half-pint phial so as to give a shock sensible
to

to the elbows. The kite, after being up for about one hour, fell to the ground, having its paper, which was not properly varnished, almost intirely torn off by the violence of the wind and the rain.

September the 14th. The kite was raised with a strong north wind at half past three P. M. The Electricity was positive, and pretty strong, the index of the electrometer being generally about 20° *. The weather was rather cold, and very thick clouds were gradually approaching the zenith. The kite was pulled down at half past four P. M.

N. B. At night the aurora borealis was very strong, and several flashes of lightning were seen near the horizon towards the north.

September the 23d. A small kite was raised at half past ten o'clock in the morn-

* The index of the electrometer in general raises higher or falls lower, according as the kite comes nearer to, or goes farther from the zenith; the length of the string remaining the same.

ing, and it was kept up for eleven hours successively, *viz.* till half past nine P. M. The string, which was only a common twine, without a wire, was constantly electrified positively, although in a very small degree. About nine o'clock the Electricity appeared stronger, so that a small phial, charged at the string, gave a pretty sensible shock. The weather was very clear, and warm; but in the night no aurora borealis, or any other electrical appearance, was perceived. The wind was east by south, and so weak that the kite was kept up with great difficulty.

October the 10th, 1775. The weather being clear, and the wind blowing strong from the south west, the kite was raised at eleven o'clock A. M. with ninety yards of string, which had a copper thread twisted in*. The wind, during the experiment, increased and decreased several times; and the Electricity, which was positive, as it appeared by the index of the electrometer,

* Such string as this was used in all the following experiments.

also increased and decreased. At noon the violence of the wind caused the kite to fall. At half past four o'clock, the wind being a little more moderate, the kite was raised again. The Electricity was also positive, and seemed rather stronger than it had been in the morning. The weather at this time was cloudy; the clouds appearing much thicker near the horizon than about the zenith. The kite was pulled down at half past five o'clock, and at half after seven was raised again; every phenomenon continuing the same. At eight o'clock, while I was pulling the kite in, I insulated the string when only thirty-five yards of it were out, and was surprised to find, that now the Electricity was as strong as it had been, when all the string was out, which was ninety yards long. It must however be remarked, that at this time a few flashes of lightning were seen among the clouds, which were pretty thick about the horizon. At a quarter past eleven o'clock the kite was raised again, which was the fourth time of raising it that day; the weather then being very clear, and the wind the same as in the afternoon. The Electricity

was very weak, but constantly positive. The kite was pulled down, after having been up a few minutes only.

October the 16th. At about two P. M. a thick fog being just cleared up, the weather became clear, and the wind began to blow from the south south west. The kite was raised with one hundred and twenty yards of string, and it was kept up no longer than a quarter of an hour. The Electricity was positive, and pretty strong; the index of the electrometer being about 15° . At half past three o'clock the kite was raised again, the weather being very little cloudy. At half past four o'clock the clouds became very thick, and in a short time it began to rain, which increased the Electricity of the kite, without changing its quality; the index of the electrometer arriving to 20° . The kite was pulled down at five o'clock.

October the 18th. After having rained a great deal in the morning, and night before, the weather became a little clear in the afternoon, the clouds appearing separated,

rated, and pretty well defined. The wind was west, and rather strong, and the atmosphere in a temperate degree of heat. In these circumstances, at three P. M. I raised my electrical kite with three hundred and sixty feet of string. After that the end of the string had been insulated, and a leather-ball, covered with tin-foil, had been hung to it, I tried the power and quality of the Electricity, which appeared to be positive, and pretty strong. In a short time a small cloud passing over, the Electricity increased a little; but the cloud being gone, it decreased again to its former degree. The string of the kite was now fastened by the silk lace to a post in the yard of the house wherein I lived, which was situated near Islington, and I was repeatedly charging two coated phials, and giving shocks with them:—while I was so doing, the Electricity, which was still positive, began to decrease, and in two or three minutes time it became so weak, that it could be hardly perceived with a very sensible cork-ball electrometer. Observing at the same time that a large and black cloud was approaching the zenith (which, no

doubt, caused the decrease of the Electricity) indicating imminent rain, I introduced the end of the string through a window, in a first-floor room, wherein I fastened it by the silk lace to an old chair. The quadrant electrometer was set upon the same window, and was, by means of a wire, connected with the string of the kite. Being now three quarters of an hour after three o'clock, the Electricity was absolutely unperceivable; however, in about three minutes time, it became again perceivable, but now upon trial was found to be negative; it is therefore plain, that its stopping was nothing more than a change from positive to negative, which was evidently occasioned by the approach of the cloud, part of which by this time had reached the zenith of the kite, and the rain also had begun to fall in large drops.—The cloud came farther on;—the rain increased, and the Electricity keeping pace with it, the electrometer soon arrived to 15° . Seeing now, that the Electricity was pretty strong, I began again to charge the two coated phials, and to give shocks with them; but the phials had not been charged
above

above three or four times, before I perceived that the index of the electrometer was arrived to 35° , and was keeping still increasing. The shocks now being very smart, I desisted from charging the phials any longer ; and, considering the rapid advance of the Electricity, thought to take off the insulation of the string, in case that if it should increase farther, it might be silently conducted to the earth, without causing any bad accident, by being accumulated in the insulated string. To effect this, as I had no proper apparatus near me, I thought to remove the silk lace, and fasten the string itself to the chair ; accordingly, I disengaged the wire that connected the electrometer with the string ; laid hold of the string ; untied it from the silk lace, and fastened it to the chair ; but while I effected this, which took up less than half a minute of time, I received about a dozen, or fifteen very strong shocks, which I felt all along my arms, in my breast, and legs ; shaking me in such a manner, that I had hardly power enough to effect my purpose, and to warn the people in the room to keep their distance. As soon as I took my hands off
the

the string, the Electricity (in consequence of the chair being a bad Conductor) began to snap between the string and the shutter of the window, which was the nearest body to it. The snappings, which were audible at a good distance out of the room, seemed first isochronous with the shocks which I had received, but in about a minute's time, oftner; so that the people of the house compared their sound to the rattling noise of a jack going when the fly is off. The cloud now was just over the kite; it was black, and well defined, of almost a circular form, its diameter appearing to be about 40° ; the rain was copious, but not remarkably heavy. As the cloud was going off, the electrical snapping began to weaken, and in a short time became unaudible. I went then near the string, and finding the Electricity weak, but still negative, I insulated it again, thinking to keep the kite up some time longer; but observing that another larger and denser cloud was approaching apace towards the zenith, as I had then no proper apparatus at hand, to prevent every possible bad accident, I resolved to pull the kite in; accordingly a gentleman, who
was

was by me, began pulling it in, while I was winding up the string. The cloud was now very nearly over the kite, and the gentleman, who was pulling in the string, told me, that he had received one or two slight shocks in his arms, and that if he were to feel one more, he would certainly let the string go; upon which I laid hold of the string, and pulled the kite in as fast as I could, without any farther observation; being then ten minutes after four o'clock.

N. B. There was neither thunder or lightning perceived that day, nor indeed for some days before or afterwards.

November the 8th, 1775. The wind being north-west, and just sufficient, the kite was raised at three quarters past eleven A. M. with one hundred and twenty yards of string. The Electricity was positive, and weak, the weather being cloudy. At noon the clouds grew thicker, and the Electricity quite vanished; however, in a few seconds it returned, and from this time it evidently kept increasing and decreasing, according as the clouds became thinner

thinner or thicker. At forty minutes after one o'clock the Electricity vanished again; a thick cloud then covering almost the whole hemisphere; but as a little rain began to fall, the Electricity returned, and it was still positive. At three quarters past three o'clock the clouds began to grow thin, and the Electricity increased a little; but at this time I was obliged to pull the kite in. The index of the electrometer in this experiment seldom arrived to 6° .

November the 16th. The weather being very clear and frosty, the kite was raised at a quarter past ten A. M. with one hundred and twenty yards of string. The Electricity was positive, and pretty strong, the index of the electrometer going from 9° to 15° ; raising as the wind blew stronger, and the kite was more elevated, and *vice versa*. At a quarter past three o'clock the wind, which was north-north-west, intirely failing, the kite fell,

November the 17th. The weather being exceedingly damp, and the fog so dense, that the houses at about a quarter of a mile distance

distance could not be distinguished, the kite was raised at two P. M. with one hundred and ten yards of string, while it was raining, but very little. The Electricity was positive, and so weak that the cork-balls of an electrometer diverged about three quarters of an inch. The wind being very violent, I was obliged to pull the kite in, after having been up for about five minutes.

December the 5th, 1775. The weather being equally cloudy, and the wind west by north, and hardly sufficient, the kite was raised at a quarter past three P. M. with one hundred and twenty yards of string. The Electricity was positive, and so weak as to cause the cork-balls of an electrometer to diverge about an inch. At a little after four o'clock the kite was pulled in; and at eight o'clock in the evening it was raised again. At this time the Electricity was much stronger than in the afternoon, but constantly positive. The weather clearing up, the clouds were driven away by the wind, which was now a little stronger than in the afternoon. At forty minutes after

after eight o'clock the sky was clear, the moon and stars appearing very bright; except that a few thin clouds were yet to be seen near the horizon. The index of the electrometer was now going from 15° to 20° . At ten minutes after nine o'clock the kite was drawn in.

N. B. No aurora borealis was to be seen.

December the 20th. The weather being cloudy and hazy, the kite was raised at three quarters after ten o'clock A. M. with one hundred and forty yards of string. The Electricity was positive, and pretty strong, the index of the electrometer going from 16° to 21° . At half past one P. M. the weather growing a little clearer, I pulled the kite down; and, after having interposed a silk ribband between its loop and the extremity of the string, so as to insulate the kite, I raised it again with the same length of string; and, after I had insulated the lower extremity of the string, I observed that the intensity of the Electricity, as it appeared by the index of the electrometer,

trometer, was, as nearly as could be determined, the same as before, *i. e.* when the kite was not insulated with respect to the string.

At two o'clock P. M. I pulled the kite down, and found upon observation, that the silk ribband had contracted no moisture, so that the kite was perfectly insulated by it. This experiment of insulating the kite I have often repeated at other times, and have always met with the same success; hence it appears, that it is the string, and not the kite, which in general collects the Electricity from the air. The kite therefore in general is only useful to extend the string high into the open air.

January the 4th, 1776. The frost having been very hard during the day and night before, the wind began to blow very strong from the south at two o'clock A. M. which occasioned a sudden thaw and a copious rain. At eight o'clock A. M. at which time the kite was raised, the hemisphere appeared like a uniform dark canopy, under which several small, irregular, and darker

darker clouds were running very fast; the rain was constant, but not remarkably heavy. As soon as the string of the kite was insulated, the Electricity, which was negative, began to snap from it, to the shutter of the window and other bodies near; the index of the electrometer arrived to 40° , and it would have certainly gone farther, if the apparatus had been drier; but the air was so damp, that it was almost impossible to keep any part of the apparatus sufficiently free from moisture. The Electricity, however, gradually decreased, so that at ten o'clock A. M. at which time the kite was pulled in, the index of the electrometer was at a little above 12° . The coated phials in this experiment were charged surprisingly quick; three or four seconds of time being sufficient to charge two half-pint phials completely.

January the 11th. The ground was covered with ice and snow, and the atmosphere was so hazy, that the houses at a mile distance could not be perceived. The wind was south-east by south, and just sufficient to raise the kite, which was raised
at

at three o'clock P. M. with one hundred and twenty-four yards of string, and kept up till half an hour after midnight. When the kite was first raised it began to thaw, but as soon as it was dark it began to freeze again very hard. The Electricity was positive, and pretty strong, the index of the electrometer being about 13° . At half past four o'clock I let out thirty-four yards more of string, so that all the string the kite now had, was one hundred and fifty-eight yards. With this addition of string the Electricity increased, so that the index of the electrometer arrived to 17° . At half after five o'clock the wind began to increase, and the Electricity to decrease, until the index of the electrometer arrived to 6° . At three quarters past six o'clock the index of the electrometer was about 13° , and at seven o'clock it arrived to 20° ; the wind being now quite east. At a quarter past seven o'clock the index of the electrometer was about 25° . From this time the wind and the Electricity began both to decrease, so that at nine o'clock the index of the electrometer was about 10° . At eleven o'clock the wind increased. At

twelve o'clock the wind was very strong, and the index of the electrometer was about 6° . At half past twelve o'clock the index of the electrometer was between 3° and 4° ; but the wind being grown very violent, the string broke very near the window, and was lost with the kite.

N. B. A few minutes after the kite was lost, it began to snow copiously.

January the 26th. The frost being very intense, as it had been for about three weeks, and actually snowing, I raised the kite, with seventy yards of string; but before the string was insulated, it ceased to snow, and the weather began to clear up, and soon became very serene. The Electricity was positive, and very strong, the index of the electrometer being about 32° . At eleven o'clock the string broke, and the kite fell, after having been up for above three quarters of an hour.

February the 17th, 1776. The weather being cloudy, rainy, and so hazy, that the houses at half a mile distance could not be
discerned,

discerned, the kite was raised at three quarters past eleven o'clock A. M. with one hundred and seventy-five yards of string. The wind was pretty strong; the Electricity was negative, and also strong; the index of the electrometer being about 20° . In about five minutes time the rain ceased, the wind weakened, and shifted a little towards the south; and the Electricity changed from negative to positive. The index of the electrometer was now about 15° . In two or three minutes time, it began to rain again, and continued so for the greatest part of that day; the wind became very weak, and the Electricity changed again from positive to negative, and continued so till half an hour after noon; at which time the wind became so weak that I was obliged to pull the kite in.

February the 19th. The sky being full of pretty well defined clouds, and the wind west-north-west, the kite was raised at half past three o'clock P. M. with one hundred and seventy-five yards of string. The Electricity was positive and strong;

the index of the electrometer going from 10° to 20° . At three quarters past three o'clock a dense cloud passed over the kite, which occasioned the index of the electrometer to descend to 4° . As the cloud went away, the electrometer elevated its index. At four o'clock the kite was pulled down.

April the 8th, 1776. The weather was clear, and the northern light very strong. The kite was raised for a few minutes at nine o'clock P. M. with one hundred and seventy-five yards of string, the wind being north-north-west, and pretty strong. The Electricity was positive, and, as I could judge, the index of the electrometer would have arrived to 15° .

May the 15th, 1776. The weather being cloudy, and the wind north, the kite was raised at three o'clock P. M. with one hundred and seventy yards of string. The Electricity was at first exceedingly weak, and, as I imagine (for I had not time to examine it) positive. But a dense cloud passing over the kite, the Electricity vanished;

nished ; and, as a few drops of rain fell, a very weak negative Electricity appeared, which soon increased, so as to cause the index of the electrometer to arrive to 15° . The rain, however, in a few minutes ceased, and the Electricity gradually decreased and vanished. A very weak positive Electricity immediately took place ; but, as another denser cloud passed over, and a few very small drops of rain fell, the positive Electricity vanished, and the negative took place. The cloud and rain soon went off, and the Electricity became again positive, and continued so till the kite was pulled down. According as the clouds, which passed continually over the kite, were thinner or thicker, so the Electricity was more or less intense; sometimes causing the index of the electrometer to arrive to 5° , and at other times being scarce perceivable with the cork-ball electrometer. At five o'clock the kite was pulled in, the weather being then pretty clear, and the index of the electrometer at 3° . The wind, during this experiment, was stronger or weaker, according as the clouds which passed over were

thicker or thinner. At half past seven o'clock in the evening of the same day, the kite was raised again, with the same length of string, the wind being then rather strong, and the weather pretty clear. The Electricity was positive, and the index of the electrometer stood at 10° ; but as some clouds came from the north, the Electricity began to decrease, and by eight o'clock it just separated the balls of an electrometer, the hemisphere being then entirely covered by clouds. At half past eight o'clock the kite was pulled down, the clouds over the kite being then very thin, and the index of the electrometer at 5° .

June the 4th, 1776. The weather being cloudy, and the wind on the south-south-west, the kite was raised at one o'clock P. M. with one hundred and seventy yards of string. The Electricity was positive, and the index went from 1° to 7° . At three quarters past one o'clock the clouds began to be dissipated, and the Electricity increased a little. At two o'clock the kite was pulled in.

June

June the 17th. The weather being cloudy, and the wind south-west, the kite was raised at five o'clock P. M. with one hundred and seventy yards of string. The Electricity was positive, and the index of the electrometer went from 10° to 16° . In this experiment the clouds, whether thicker or thinner, seemed to have no effect upon the Electricity of the kite. At a quarter past six o'clock the kite was pulled in.

June the 20th. The weather being cloudy, and the wind east, and just sufficient, the kite was raised at three quarters past three P. M. with one hundred and seventy yards of string. The Electricity was positive, and the index of the electrometer stood about 8° . At five o'clock the weather began to clear up, and the Electricity to increase; so that in half an hour's time, the index of the electrometer arrived to 17° ; and at six o'clock it stood at 25° . But the wind suddenly failing about this time, the kite fell.

January the 8th, 1777. The weather
C c 4 being

being frosty and clear, and the wind north, and pretty strong, the kite was raised at four o'clock P. M. with one hundred and seventy yards of string. The Electricity was positive and strong, the index of the electrometer being at 36° . The spark taken from the small prime Conductor was remarkably pungent in this experiment, although it was hardly a quarter of an inch long. At a quarter past five o'clock the kite was pulled in.

General Laws, deduced from the Experiments performed with the electrical Kites.

I. The air appears to be electrified at all times; its Electricity is constantly positive, and much stronger in frosty, than in warm weather*; but it is by no means less in the night than in the day-time†.

II. The

* My observations upon the Electricity of the atmosphere have been made in almost every degree of temperature, from 15° to 80° of FARENHEIT'S thermometer.

† In all my experiments, it happened only once that the string of the kite gave no signs of Electricity; it was one afternoon, when the weather was warm,

II. The presence of the clouds generally lessens the Electricity of the kite: sometimes it has no effect upon it; and it is very seldom that it increases it a little.

III. When it rains, the Electricity of the kite is generally negative, and very seldom positive.

IV. The aurora borealis seems not to affect the Electricity of the kite.

V. The electrical spark taken from the string of the kite, or from any insulated Conductor connected with it, especially when it does not rain, is very seldom longer than a quarter of an inch; but it is exceedingly pungent. When the index of the electrometer is not higher than 20° , the person that takes the spark will feel

warm, and the wind so weak, that the kite was raised with difficulty, and could hardly be kept up for a few minutes; in the evening, however, the wind, which in the day-time had been north-west, shifted to the north-east, blowing a little stronger; I then raised the kite again, being half past ten o'clock, and obtained, as usual, a pretty strong positive Electricity.

the

the effect of it in his legs; it appearing more like the discharge of an electric jar, than the spark taken from the prime Conductor of an electrical machine.

VI. The Electricity of the kite is in general stronger or weaker, according as the string is longer or shorter; but it does not keep any exact proportion to it: the Electricity, for instance, brought down by a string of a hundred yards, may raise the index of the electrometer to 20° ; when, with double that length of string, the index of the electrometer will not go higher than 25° .

VII. When the weather is damp, and the Electricity is pretty strong, the index of the electrometer, after taking a spark from the string, or presenting the knob of a coated phial to it, rises surprisingly quick to its usual place; but in dry and warm weather, it rises exceeding slow.

These few laws are, in short, the deduction of all my experiments performed with the kites, during the course of about two years.

years. How far they may be of use, or may coincide with the observations of other experimentators, I will not pretend to say. My experiments have been performed at Islington, and perhaps the result of similar ones may be different at other places, especially under different climates; I wish, therefore, that they may be accurately repeated in other places, and their result may be compared together; in order to determine, if possible, something satisfactory, relative to the cause of that perpetual Electricity which exists in the atmosphere, and which, very probably, occasions the Electricity of the clouds.

C H A P. III.

Experiments performed with the Atmospheric Electrometer, and the Electrometer for the Rain.

F I G. 1. of Plate III. represents a very simple instrument, which I have contrived for the purpose of making observations

vations on the Electricity of the atmosphere; and which, on several accounts, seems to be the most useful for that purpose. A B is a common jointed fishing-rod, without the last or smallest joint. From the extremity of this rod proceeds a slender glass tube C, covered with sealing-wax; and having a cork D, at its end, from which a pith-ball electrometer is suspended. H G I is a piece of twine fastened to the other extremity of the rod, and supported at G by a small string F G. At the end I of the twine a pin is fastened, which, when pushed into the cork D, renders the electrometer E uninfused.

When I would observe the Electricity of the atmosphere with this instrument, I thrust the pin I into the cork D, and holding the rod by its lower end A, project it out from a window in the upper part of the house into the air, raising the end of the rod with the electrometer, so as to make an angle of about 50° or 60° with the horizon. In this situation I keep the instrument for a few seconds, and then pulling the twine at H, I disengage the pin from

from the cork D; which operation causes the string to drop in the dotted situation K L, and leaves the electrometer insulated and electrified, with an Electricity contrary to that of the atmosphere.—This done, I draw the instrument into the room, and examine the quality of the Electricity, without obstruction either from wind or darkness.

With this instrument I have made observations on the Electricity of the atmosphere, several times in a day for several months, and from them I have deduced the following general observations, which seem to coincide with those made with the electrical kites.

I. That there is in the atmosphere, at all times, a quantity of Electricity; for, whenever I use the above-described instrument, it always acquires some Electricity.

II. That the Electricity of the atmosphere, or fogs, is always of the same kind, namely positive; for the electrometer
is

s always negative, except when it is evidently influenced by heavy clouds near the zenith; as appears by the observations made the 19th of October, in the following specimen of the journal.

III. That in general, the strongest Electricity is observable in thick fogs, and also in frosty weather; and the weakest, when it is cloudy, warm, and very near raining: but it does not seem to be less by night than in the day.

IV. That in a more elevated place the Electricity is stronger than in a lower one; for, having tried the atmospherical electrometer, both in the stone and iron gallery on the cupola of St. Paul's Cathedral, I found that the balls diverged much more in the latter than in the former less elevated place: hence it appears, that, if this rule takes place at any distance from the earth, the Electricity in the upper regions of the atmosphere must be exceedingly strong.

The

The following is the most remarkable part of the journal of the observations made with the above-described atmospheric electrometer, in which I have noted the Electricity of the electrometer, *i. e.* the contrary of that in the atmosphere.

N. B. The stroke ——— signifies as above.

Time of observation.	Clouds.	Fog.	Wind.	Opening of the electrometer in inches.	Quality of the Electricity.
October the 19th, 1776, $\frac{1}{2}$ past 10 o'clock 11	Cloudy	Very little at a distance	Very strong	$\frac{1}{10}$	Negative
2	Heavy clouds		Violent	$\frac{3}{4}$	Positive
$\frac{1}{4}$ past 2	Less clouds		Little	1	Negative
3	Few at a distance	Exceedingly thick		$\frac{1}{2}$	
November the 6th, 11 o'clock, P. M.		Hardly any		1	
November the 8th, 12 at noon		Very little		$\frac{3}{4}$	
November the 13th, 10 o'clock, A. M.	Cloudy	Little at a distance	Pretty strong	Very little	
10 P. M.				$\frac{1}{3}$	
November the 17th, 11 o'clock, P. M.			Violent	$\frac{1}{4}$	
12			Very little		
November the 28th, 10 o'clock, A. M.			Little	$\frac{1}{2}$	
December the 20th, $\frac{1}{2}$ past 9 o'clock, P. M.	Cloudy	Little	Hardly any		
February the 6th, 1777, 2 o'clock, P. M.			Very little	$\frac{1}{2}$	
February the 7th, 12 at noon				$\frac{1}{2}$	
8				$\frac{1}{2}$	
February the 27th, 12 o'clock, P. M.			Hardly any		
March the 26th, 11 o'clock, P. M.	Few on the north	Very little		Very little	
				$\frac{1}{10}$	

The electrometer for the rain, in principle is nothing more than an insulated instrument to catch the rain, and by a pith-ball electrometer to shew the quantity and quality of its Electricity.

Fig. 2. of Plate III. represents an instrument of this kind, which I have frequently used, and after several observations, have found to answer very well. A B C I is a strong glass tube about two feet and a half long, having a tin funnel, D E, cemented to its extremity, which funnel defends part of the tube from the rain. The outside surface of the tube from A to B is covered with sealing-wax; so also is the part of it which is covered by the funnel. F D is a piece of cane, round which several brass wires are twisted in different directions, so as to catch the rain easily, and at the same time to make no resistance to the wind. This piece of cane is fixed into the tube, and a slender wire proceeding from it goes through the bore of the tube, and communicates with the strong wire A G, which is thrust into a piece of cork fastened to the end A of the tube. The end G of the
wire

wire A G is formed into a ring, from which I suspend a more or less sensible pith-ball electrometer, as occasion requires.

This instrument is fastened to the side of the window-frame, where it is supported by strong brass hooks at C B, which part of the tube is covered with a silk lace, in order to adapt it better to the hooks. The part F C is out of the window, with the end F a little elevated above the horizon. The remaining part of the instrument comes through a hole in one of the lights of the sash, within the room, and no more of it touches the side of the window than the part C B.

When it rains, especially in passing showers, this instrument, standing in the situation above described, is frequently electrified; and, by the diverging of the electrometer, the quantity and quality of the Electricity of the rain may be observed, without any danger of a mistake. With this instrument I have observed, that the rain is generally, though not always, electrified negatively, and sometimes so strong-

ly that I have been able to charge a small coated phial at the wire A G.

This instrument should be fixed in such a manner, that it may be easily taken off from the window, and replaced again, as occasion requires; for it will be necessary to clean it very often, particularly when a shower of rain is approaching.

I shall conclude this chapter with the description of a pocket electrometer, fig. 5 and 6. of Plate III. that I have lately constructed, and which, on several accounts, seems preferable to those of the most sensible sort now in use. The case, or handle of this electrometer is formed by a glass tube, about three inches long, and three-tenths of an inch in diameter, half of which is covered with sealing-wax. From one extremity of this tube, *i. e.* that without sealing-wax, a small loop of silk proceeds, which serves occasionally to hang the electrometer on a pin, &c. To the other extremity of the tube a cork is adapted, which, being cut tapering on both ends, can fit the mouth of the tube with either end.

end. From one extremity of this cork, two linen threads proceed, a little shorter than the length of the tube, suspending each a little *cone* of pith of elder. When this electrometer is to be used, that end of the cork which is opposite to the threads is pushed into the mouth of the tube; then the tube forms the insulated handle of the pith electrometer as represented fig. 6. Plate III. But when the electrometer is to be carried in the pocket, then the threads are put into the tube, and the cork stops it, as represented fig. 5. The peculiar advantages of this electrometer are, its convenient small size, its great sensibility, and its continuing longer in good order than any other I have yet seen.

Fig. 4. of Plate III. represents a case to carry the above-described electrometer in. This case is like a common tooth-pick case, except that it has a piece of amber fixed on one extremity A, which may occasionally serve to electrify the electrometer negatively, and on the other extremity it has a piece of ivory fastened upon a piece of amber B C. This amber B C serves only to

insulate the ivory, which, when insulated, and rubbed against woollen cloths, acquires a positive Electricity; and it is therefore useful to electrify the electrometer positively.

C H A P. IV.

Experiments made with the Electrophorus, commonly called a Machine for exhibiting perpetual Electricity.

IN fig. 9. of Plate III. there are represented some Plates, commonly called the Machine for exhibiting perpetual Electricity, or the *Electrophorus*. This machine consists of two plates, one of which, B, is a circular glass plate, covered on one side with some sulphureous or resinous electric, most commonly with a composition made of equal parts of rosin, shell-lac, and sulphur; the other plate A, is a brass plate, or a board covered with tin-foil, which is nearly of the same dimensions as the electric plate, and it is furnished with a glass handle I, which, by means

means of a brass or wooden socket, is screwed into its center. This machine is the invention of an Italian philosopher (Mr. VOLTA of Como) and its use is the following :

First, the plate B is excited, by rubbing its coated side with a piece of new white flannel, and when excited as much as possible, is set upon the table with the coated side uppermost. Secondly, the metal plate is laid upon the excited electric, as represented in the figure. Thirdly, the metal plate, is touched with the finger or any other Conductor, which, on touching the plate, receives a spark from it. Lastly, the metal plate A, being held by the extremity of its glass handle I, is separated from the electric plate ; and, after it is elevated above that plate, it will be found strongly electrified, with an Electricity contrary to that of the electric plate, in which case it will give a very strong spark to any Conductor brought near it. By setting the metal upon the electric plate, touching it with the finger, and separating it successively, a great number of sparks may be

obtained apparently of the same strength, and that without exciting again the electric plate. If these sparks are repeatedly given to the knob of a coated phial, this will presently become charged.

The action of these plates depends upon a principle long ago discovered, *viz.* the power that an excited electric has to induce a contrary Electricity in a body brought within its sphere of action; the metal plate, therefore, when set upon the excited electric, acquires a contrary Electricity, by giving its electric fluid to the hand, or other Conductor that touches it, when set upon a plate positively electrified; or acquiring an additional quantity of fluid from the hand, &c. when set upon a plate electrified negatively.

As to the continuance of the virtue of this electric plate, when once excited, without repeating the excitation, I think there is not the least foundation for believing it perpetual, as some persons have supposed; it being nothing more than an excited electric, it must gradually lose its power,

power, by imparting continually some of its Electricity to the air, or other substances contiguous to it. Indeed its Electricity, although it could never be proved to be perpetual by experiments, lasts a very long time, it having been observed to be pretty strong several days, and even weeks after excitation. The great duration of the Electricity of this plate, I think, depends upon two causes: first, because it does not lose any Electricity by the operation of putting the metal plate upon it, &c.; and secondly, because of its flat figure, which exposes it to a less quantity of air, in comparison with a stick of sealing-wax, or the like, which being cylindrical, exposes its surface to a greater quantity of air, which is continually robbing the excited electrics of their virtue.

The first experiments that I made relative to this machine, were with a view to discover which substance would answer best for coating the glass plate, in order to produce the greatest effect. I tried several substances either simple or mixed, and at last I observed, that the strongest in power,

as well as the easiest I could construct, were those made with the second sort of sealing-wax *, spread upon a thick plate of glass †. A plate that I made after this manner, and no more than six inches in diameter, when once excited, could charge a coated phial several times successively, so strong as to pierce a hole through a card with the discharge. Sometimes the metal plate, when separated from it, was so strongly electrified, that it darted strong flashes to the table upon which the electric plate was laid, and even into the air, besides causing the sensation of the spi-

* It is remarkable, that sometimes they will not act well at first ; but they may be rendered very good, by scraping with the edge of a knife the shining or glossy surface of the wax. This seems analogous to the well-known property of glass ; which is, that new cylinders or globes, made for electrical purposes, are often very bad electrics at first, but that they improve by being worked, *i. e.* by having their surface a little worn. Paper also has this property.

† I have lately seen some of those plates, constructed by Mr. G. ADAMS, which acted exceedingly well ; and they were made with a composition of two parts of shell-lac, and one part of Venice turpentine, without any glass plate.

der's web upon the face brought near it, like an electric strongly excited. The power of some of my plates is so strong, that sometimes the electric plate adheres to the metal, when this is lifted up; nor will they separate, even if the metal plate is touched with the finger, or other Conductor.

If, after having excited the sealing-wax, I lay the plate with the wax upon the table, and the glass uppermost, *i. e.* contrary to the common method, then, on making the usual experiment of putting the metal plate on it, and taking the spark, &c. I observe it to be attended with the contrary Electricity; that is, if I lay the metal plate upon the electric one, and while in that situation touch it with an insulated body, that body acquires the positive Electricity, and the metallic, removed from the electric plate, appears to be negative; whereas it would become positive if laid upon the excited wax. This experiment, I find, answers in the same manner, if an electric plate is used which has the sealing-wax coating

coating on both sides, or one of Mr. ADAMS's, which has no glass plate.

If the brass plate, after being separated from, be presented with the edge toward the wax, lightly touching it, and thus be drawn over its surface, I find that the Electricity of the metal is absorbed by the sealing-wax, and thus the electric plate loses part of its power; and if this operation is repeated five or six times, the electric plate loses its power intirely, so that a new excitation is necessary in order to revive it.

If, instead of laying the electric plate upon the table, it is placed upon an electric stand, so as to be accurately insulated, then the metal plate set on it acquires so little Electricity that it can only be discovered with an electrometer; which shews, that the Electricity of this plate will not be conspicuous on one side of it, if the opposite side is not at liberty either to part with, or acquire more of the electric fluid. In consequence of this experiment, and in order to ascertain how the opposite sides of the

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the electric plate would be affected in different circumstances, I made the following experiments :

Upon an electric stand E, fig. 9. Plate III. I placed a circular tin plate, nearly six inches in diameter, which by a slender wire H communicated with an electrometer of pith-balls G, which was also insulated upon the electric stand F. I then placed the excited electric plate D, of six inches and a quarter in diameter, upon the tin plate, with the wax uppermost, and on removing my hand from it, the electrometer G, which communicated with the tin plate, *i. e.* with the under side of the electric plate, immediately opened with negative Electricity. If, by touching the electrometer, I took that Electricity off, the electrometer did not afterwards diverge. But if now, or when the electrometer diverged, I presented my hand open, or any other uninsulated Conductor, at the distance of about one or two inches, over the electric plate, without touching it, then the pith-balls diverged; or if they diverged before, came together, and immediately diverged again

again with positive Electricity ;—I removed the hand, and the balls came together ;—approached the hand, and they diverged ; and so on.

If, while the pith-balls diverged with negative Electricity, I laid the metal plate, holding it by the extremity K of its glass handle, upon the wax, the balls came, for a little time, towards one another, but soon opened again with the same, *i. e.* negative Electricity.

If, whilst the metallic rested upon the electric plate, I touched the former, the electrometer immediately diverged with positive Electricity, which if, by touching the electrometer, I took off, the electrometer continued without divergence.—I touched the metal plate again, and the electrometer opened again ; and so on for a considerable number of times, until the metal plate had acquired its full charge. On taking now the metal plate up, the electrometer G instantly diverged with strong negative Electricity.

I repeated the above-described experiments with this only difference in the disposition of the apparatus, *i. e.* I laid the electric plate D, with the excited sealing-wax, upon the circular tin plate, and the glass uppermost ; and the difference in their result was, that where the Electricity had been positive in the former disposition of the apparatus, it now became negative, and *vice versa* ; except that, when I first laid the electric plate upon the tin, the electrometer G diverged with negative Electricity, as well in this as in the other disposition of the apparatus.

I repeated all the above experiments with an electric plate, which, besides the sealing-wax coating on one side, had a strong coat of varnish on the other side ; and their result was similar to that of those made with the above-described plate.

As to the explanation of these experiments, they seem to depend upon these two well-known principles, *viz.* that a body brought within the sphere of action of an electrified body, does actually acquire
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the contrary Electricity ; and that the existence of one kind of Electricity upon the surface of a substance whatever, causes the existence of the contrary Electricity upon some other substance near it.

C H A P. V.

Experiments on Colours.

HAVING accidentally observed that an electric shock, sent over the surface of a card, marked a black stroke upon a red spot of the card, I was from this induced to try what would be the effect of sending shocks over cards painted with different water-colours ; accordingly, I painted several cards with almost every colour I had, and sent shocks * over them, when they were very dry ; making use of the universal discharger, fig. 5. Plate I. The effects were as follow :

* The force generally employed was the full charge of one foot and a half of coated glass.

Vermilion

Vermilion was marked with a strong black track, about one-tenth of an inch wide. This stroke is generally single, as represented by A B, fig. 7. of Plate III; sometimes it is divided in two towards the middle, like E F; and sometimes, particularly when the wires are set very distant from one another, the stroke is not continued, but interrupted in the middle, like G H. It often, although not always, happens, that the impression is marked stronger at the extremity of that wire from which the electric fluid issues, as it appears at E, supposing that the wire C communicates with the positive side of the jar; whereas the extremity of the stroke, contiguous to the point of the wire D, is neither so strongly marked, nor surrounds the wire so much as the other extremity E.

Carmine received a faint and slender impression of a purple colour.

Verdigrise was shook off from the surface of the card, except when it had been mixed

mixed with strong gum-water, in which case it received a very faint impression.

White lead was marked with a strong black track, not so broad as that on vermilion.

Red lead was marked with a faint mark, much like carmine.

The other colours I tried, were orpiment, gambodge, sap-green, red-ink, ultramarine, Prussian blue, and a few others, which were compounds of the above; but they received no impression.

It having been insinuated, that the strong black mark, which vermilion receives from the electric shock, might possibly be owing to the great quantity of sulphur contained in the mineral, I was induced to make the following experiment:—I mixed together equal quantities of orpiment and flower of sulphur, and with this mixture, by the help, as usual, of very diluted gum-water, I painted a card; but the electric shock sent over it left not the least impression.

Desirous

Desirous of carrying this investigation on colours a little further, with a particular view to determine something relative to the properties of lamp-black and oil *, I procured some pieces of paper painted on both sides with oil colours, and, sending the charge of two feet of coated glass over each of them, by making the interruption of the circuit upon their surfaces, I observed that the pieces of paper painted with lamp-black, Prussian-blue, vermilion, and purple brown, were torn by the explosion, but white lead, Naples yellow, English ochre, and verdigrise remained unhurt.

The same shock sent over a piece of paper painted very thickly with lamp-black and oil left not the least impression. I sent the shock also over a piece of paper un-

* It has often been observed, that when the lightning has struck the masts of ships, it has passed over such parts of the masts which were covered with lamp-black and tar, or painted with lamp-black and oil, without the least injury, at the same time that it has shivered the uncoated parts, in such a manner as to render the masts useless. For a particular account of such facts, see the Phil. Trans. vol. XLVIII. and LXVII.

E e

equally

equally painted with purple brown, and the paper was torn where the paint laid very thin, but remained unhurt where the paint was evidently thicker. These experiments I repeated several times, and with some little variation, which naturally produced different effects ; however, they all seem to point out the following proposition.

I. A coat of oil paint, over any substance, defends it from the effects of such an electric shock, as would otherwise injure it ; but by no means defends it from any electric shock whatever. II. No one colour seems preferable to the others, if they are equal in substance, and equally well mixed with oil ; but a thick coating does certainly afford a better defence than a thinner one.

By rubbing the above-mentioned pieces of paper, I find that the paper painted with *lamp-black and oil* is more easily excited, and acquires a stronger Electricity, than the papers painted with the other colours ; and perhaps on this account it may be, that
lamp-

lamp-black and oil might resist the shock somewhat better than the other paints.

It is remarkable, that vermilion receives the black impression, when painted with linseed-oil, nearly as well as when painted with water. The paper painted with white lead and oil, receives also a black mark; but its nature is very singular. The track, when first made, is almost as dark as that marked on white lead, painted with water, but it gradually loses its blackness, and in about one hour's time (or longer, if the paint is not fresh) it appears without any darkness; and when the painted paper is laid in a proper light, appears only marked with a colourless track, as if made by a finger-nail. I sent the shock also over a piece of board, which had been painted with white lead and oil about four years before, and the explosion marked the black track upon this also; this track however was not so strong, nor vanished so soon as that marked upon the painted paper, but in about two days time it also vanished intirely.

C H A P. VI.

Promiscuous Experiments.

OBServing that a strong spark may be obtained from the metal plate belonging to Mr. VOLTA's machine, described in the fourth chapter of this Part, when not the least spark can be obtained from the electric plate itself, I was naturally induced to make use of the above-mentioned metallic plate, to discover the Electricity of very weak electrics; which otherwise would be either inobservable, or so small as not to permit its quality to be ascertained. Accordingly I constructed several such plates of different sizes, beginning from that of a common metal button fastened upon a stick of sealing-wax; and by using them, I obtained a very sensible Electricity from the hairs of my legs, when stroked, and of my head, or any part that I have tried of my body, or the head of almost any other person.

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In this manner I obtain such strong sparks from the back of a cat, a hare's skin, a rabbit's skin, a piece of flannel, or of paper, that I can presently charge a coated phial with either of those, and so strongly, as to pierce a hole through a card with its discharge.

I have often observed that, when stroking a cat with one hand, and holding it with the other, I feel frequent smart pricklings on different parts of that hand, which holds the animal. In these circumstances very pungent sparks may be drawn from the tips of the ears of the cat.

Smooth glass rubbed with a rabbit's skin, dry and warm, acquires, I find, the *negative* Electricity; but if the skin is cold, the glass is excited positively. Sometimes smooth glass may be excited negatively with new white flannel, clean and dry, and also with a hare's skin.

Observing the strong electric power of new white flannel, I thought that a piece of it, rolled round the globe of an electrical

machine, would perhaps give a stronger Electricity to the prime Conductor than the glass itself. In order to try the truth of my supposition, I tied a large piece of flannel, dry and warm, round the globe of the machine, and for a rubber, I applied the palm of my hand; then turned the winch, first slowly, and afterwards briskly; but, contrary to my expectation, the Electricity at the prime Conductor, although positive, was so weak, that the index of the quadrant electrometer was not moved from its perpendicular situation. Surprised at this event, I resolved to take off the apparatus; but I was more surprised, when, on removing the flannel from the globe, the former appeared so strongly positive, that it darted several sparks to my arm, and other contiguous bodies, and the latter remained so strongly negative, that the electrometer upon the prime Conductor instantly elevated its index to about 45° . This experiment being several times repeated, produced always the same effect.

Having had occasion to coat a ten ounce phial for the Leyden experiment, I stuck
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the brass filings on the inside of it with varnish, agreeable to the directions given by some writers on Electricity. This phial remained about a week unused, but it happened that whilst I was charging and discharging it for some experiments, on making a discharge, it exploded with a greater noise than usual, the cork with the wire being at the same time blown out of the neck of it. Being intent upon the main experiments in hand, I omitted to examine this phenomenon; — I replaced the cork into the neck of the phial, and went on charging and discharging it again; but it had not been charged above three or four times more, when, on making a discharge, the varnish that stuck the brass filings was in a flame, which burnt the under side of the cork, and occasioned a good deal of smoke and flame to come out of the phial. Some days after, this experiment was repeated in the presence of three gentlemen, well versed in Electricity, when the cork with the wire was also pushed out of the neck of the phial; but the varnish was this last time so far burnt, that the brass filings were almost all dropped to

the bottom of the phial, and had their colour changed by the combustion.

In making some experiments, of a nature rather different from Electricity, I accidentally observed, that when I agitated some quicksilver in a glass tube, hermetically sealed, and in whose cavity the air was very much rarefied, the outside of the tube appeared sensibly electrified; its Electricity however was not constant, nor, as I first thought, in proportion to the agitation of the quicksilver. Being desirous of ascertaining the properties of such tubes, I constructed several of them, and by means of two cork-ball electrometers, observed their properties; but as they all agree in regard to the chief points, I shall only describe one, which is the best of them. This tube is represented by fig. 3. of Plate III. Its length is thirty-one inches, and its diameter is little less than half an inch. The quicksilver in it may be about three-fourths of an ounce; and in order to exhaust it of air, I closed it while the quicksilver was boiling in its opposite end.

Before

Before this tube is used, I make it a little warm, and clean it; then holding it nearly horizontal, I let the quicksilver in it run from one end of the tube to the other, by gently and alternately elevating and depressing its extremities. This operation immediately renders the outside of the tube electrical, but with the following remarkable property, *viz.* that end of the tube, where the quicksilver actually stands, is positive, and all the remaining part is negative. If by elevating this positive end of the tube a little, I let the quicksilver run to the opposite end, which was negative, then the former instantly becomes negative, and the latter positive. The positive end has always a stronger Electricity than the negative. If when one end of the tube, for instance A, is positive, *i. e.* when the quicksilver is in it, I do not take off that Electricity by touching it; then on elevating this end A, so as to let the quicksilver run to the opposite end B, it appears negatively electrified in a very small degree. If by depressing it again it be rendered positive a second time, and that positive Electricity is neither taken off, then on elevat-

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ing this end A again, it appears to be positive in a small degree: but if whilst it is positive, its Electricity be taken off, then on being elevated, it appears strongly negative.

When about two inches of each extremity of this tube is coated with tin-foil as it appears in the figure, that coating assists to render the Electricities at the extremities of the tube more conspicuous, so that sometimes they give sparks to a Conductor brought near.

In regard to the construction of such tubes (which I have made of several lengths, from nine to thirty-one inches) it is observable, that some will act very well, while others will hardly acquire any Electricity at all, even when they are made very hot. I am not yet thoroughly satisfied in respect to this difference, but suspect that the thickness of the glass is more concerned, than any thing else; it appearing that a tube, whose glass is about one-twentieth of an inch thick, answers better than either a thicker or a thinner one.

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The following Chapter contains the account of some experiments, which I made since the first publication of this Book ; for which reason, I deemed proper to relate them apart, without altering the preceding chapters, with the contents of which they are however connected.

C H A P. VII.

An Account of some new Experiments in Electricity, with the Description and Use of two new Electrical Instruments.

PROfessor LICHTENBERG of Göttingen, some time ago made an experiment upon the electrophorus, an account of which was first received in London towards the latter end of the year 1777. The phenomena attending the experiment are very entertaining and various, but I do not know that any person ever offered a satisfactory explanation of them. The author himself, in his paper entitled “ *De nova methodo naturam ac motum fluidi electrici investigandi Commentatio prior,*” wherein

in he gives an account of the experiment, does not attempt any explanation of it; contenting himself with the account only of various particulars attending it.—In brief, the experiment is as follows;

The electrophorus, that is, a plate of some resinous substance, as sulphur, rosin, gum-lac, &c. is first excited, either by rubbing or otherwise; then a piece of metal of any shape, at pleasure, as for instance, a three-legged compass, a piece of brass tube, or the like, is set upon the electrophorus, and to this piece of metal so placed, a spark is given, of the Electricity contrary to that of the plate; this done, the piece of metal is removed, by means of a stick of sealing-wax or other electric, and some powder of rosin, kept in a linen bag, is shaken upon the electrophorus: this powder will be found to fall about those points upon the plate, which the piece of metal touched, forming some radiated appearances, much like the common representations of stars; at the same time, upon the greatest part of the plate, that is, besides those stars, there is hardly

hardly any powder at all. Now, it is to be remarked, that if the plate is excited negatively, and the spark given to the metal set upon it is positive, the appearance will be as above-described; but if, on the contrary, the plate is positive and the spark is negative, then the powder of rosin will be found to fall upon those parts of the plate which in the other case it left uncovered, and to leave the stars clean; in short, it will do just the reverse of what it did in the other case; or, in other words, the powder of rosin will be attracted by those parts only of the electrophorus which are electrified positively.

When I first observed these phenomena, I thought there was no apparent reason why the powder of rosin should be attracted by those parts of the electrophorus which are positively electrified, and not by those which are negative. The two Electricities are certainly contrary to one another; but either of them attracts a non-electrified body. Insisting upon this consideration, I thought that the experiment could be explained only upon the supposition, that the powder of rosin, on its falling from the
linen

linen bag, was actually electrified negatively; in which case it would have been easy to account for the phenomena upon the well-known principle of bodies contrarily electrified attracting each other, and repelling one another when possessed of the same kind of Electricity.

In order to try the reality of my supposition by experiments, I insulated a brass plate upon a glass stand, and connected a very sensible electrometer with it; then began shaking the powder of rosin upon it, in the same manner as I had done upon the electrophorus, and in a few seconds time had the pleasure to see the electrometer diverge with a very manifest degree of negative Electricity, answering my expectations exactly. The explanation of the ingenious Professor LICHTENBERG's experiment, now became very easy and natural; for the powder of rosin being actually electrified negatively, could not be attracted, except by those parts of the electrophorus which are in a contrary state, *i. e.* electrified positively. It is observed, that powder of rosin answers better for this experiment than

than the powders of other substances ; and accordingly I find that this powder, when shaken upon the insulated brass plate, shews a stronger degree of Electricity than the other powders. Indeed the Electricity of the powder of rosin, not only when shaken upon the brass plate in the manner above-mentioned, but simply let fall upon it from a piece of paper, a spoon, &c. is very great ; half an ounce of this powder being sufficient to let the threads of the electrometer diverge as much as they possibly can.

This discovery not only affords an easy explanation of Professor LICHTENBERG's experiment upon the electrophorus, but shews a method of exciting powders, which has long been a desideratum in the science of Electricity. The method is as follows:— Insulate a metal plate upon an electric stand, and connect with it a cork-ball-electrometer ; then the powder required to be tried, being held in a spoon, or other thing, at about six inches above the plate, is to be let fall gradually upon it. In this manner the Electricity acquired by the powder, being communicated to the metal plate, and
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to the electrometer, is rendered manifest by the divergence of the threads; and its quality may be ascertained in the usual manner. See fig. the 4th of Plate IV.

It must be observed, that if the powder is of a conducting nature, like the amalgam of metals, sand, &c. it must be held in some electric substance, as a glass phial, a plate of sealing-wax, or the like. Sometimes the spoon that holds the powder may be insulated; in which case, after the experiment, the spoon will be found possessed of an Electricity contrary to that of the powder.

In performing these experiments care must be had to render the powders, and whatever they are held in, as free from moisture as possible; sometimes it being necessary to make them very warm, otherwise the experiment is apt to fail. The following are the particulars that I have observed with this new method, which however are neither numerous, nor often repeated; but they may suffice to excite
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the curiosity of those persons, who have leisure and the opportunity of repeating them more at large and in a greater variety.

Powder of rosin, whether it be let fall from paper, glass, or a metal spoon, electrifies the plate strongly negative; the spoon, if insulated, remaining strongly positive. Flower of sulphur produces the same effect, but in a little less degree. Pounded glass, let fall from a piece of paper, made dry and warm, electrifies the plate negatively, but not in so strong a degree as rosin. If it is let fall from a brass cup, it electrifies the plate positively, but in a very small degree.

Steel-filings let fall either from a glass phial or paper, electrify the plate negatively; but brass-filings, treated in the same manner, electrify the plate positively. The amalgam of tin-foil and mercury, gunpowder, or very fine emery, electrify the plate negatively, when they are let fall upon it from a glass phial. Quicksilver, from

F f a glass

a glass phial, electrifies the plate positively.

Soot from the chimney, or the ashes of common pit-coals mixed with small cinders, electrify the plate negatively, when let fall from a piece of paper.

Description of the improved atmospherical Electrometer.

Fig. the 2d of the annexed drawing is a geometrical representation of my new atmospherical electrometer, in its real size; this instrument, whose first hint I received from my friend T. RONAYNE, Esq; after various trials, I brought to the present state of perfection, as long ago as the year 1777; and immediately after, several of them were made after my pattern by Mr. ADAMS, philosophical instrument maker, in Fleet Street. The great difficulty attending the construction of this instrument, has long dissuaded my publishing any description of it; nor had I ever troubled the Royal Society with it, if the observations of several of my friends, who have used it in England and abroad,

abroad, joined to my own repeated experiments, had not indisputably confirmed its superiority to any other instrument of that kind. Its particular advantages are : I. The smallness of the size ; II. Its being always ready for experiments, without fear of entangling the threads, or having an equivocal result by the sluggishness of its motion ; III. Its being not disturbed by wind or rain ; IV. Its great sensibility ; and V. Its keeping the communicated Electricity longer than any other electrometer.

The principal part of this instrument is a glass tube C D M N, cemented at the bottom into the wooden piece A B, by which part the instrument is to be held when used for the atmosphere ; and it also serves to screw the instrument into its wooden case A B O, fig. 1. when it is not to be used *. The upper part of the tube C D M N, is shaped tapering to a smaller extremity, which is entirely covered with sealing-wax, melted by heat, and not dis-

* The whole case of this electrometer has been made also of brass, and has been found to answer better than wood, as it does not warp.

solved by spirits. Into this tapering part a small tube is cemented, the lower extremity G of which being also covered with sealing-wax, projects a short way within the tube C D M N. Into this smaller tube a wire is cemented, which with its under extremity touches the flat piece of ivory H, fastened to the tube by means of cork; the upper extremity of the wire projects about a quarter of an inch above the tube, and screws into the brass cap E F, which cap is open at the bottom, and serves to defend the waxed part of the instrument from the rain, &c. In fig. 3. this brass cap is represented as transparent, in order to shew its internal shape, and the manner in which it is screwed to the wire projecting above the tube L. The small tube L, and the upper extremity of the large tube C D M N, appear like one continued piece, on account of the sealing-wax, which covers them both. The conical corks P of this electrometer, which by their repulsion shew the Electricity, &c. are as small as they can possibly be made, and they are suspended by exceedingly fine
silver

silver wires; these wires are shaped in a ring at the top, by which they hang very loosely to the flat piece of ivory H, which has two holes for that purpose. By this method of suspension, which is applicable to every sort of electrometer, the friction is lessened almost to nothing, and thence the instrument is sensible of a very small degree of Electricity. I M, and K N, are two narrow slips of tin-foil, stuck to the inside of the glass C D M N, and communicating with the wooden bottom A B;—they serve to convey off that Electricity, which, when the corks touch the glass, is communicated to it, and being accumulated might disturb the free motion of the corks.

In regard to its use, this instrument may serve to observe the artificial, as well as the atmospherical Electricity. When it is to be used for artificial Electricity, this electrometer is set upon a table or other convenient support, then it is electrified by touching the brass cap E F with an electrified body, which Electricity will some-

times be preserved for more than an hour *; in this state, if any electrified substance is brought near the cap E F, the corks of the electrometer, by their converging or diverging more, will shew the species of that body's Electricity.

Before we proceed, it is necessary to remark, that to communicate any Electricity to this electrometer, by means of an excited electric, *e. g.* a piece of sealing-wax (which we suppose as always negatively electrified) is not very readily done in the usual manner, because of the cap E F being well rounded, and free from points or sharp edges. By the approach of the wax, the electrometer will be caused to diverge; but as soon as the wax is removed, the wires immediately collapse. The best method to electrify it, is to bring the excited wax so near the cap, that one or both the corks may touch the side of the bottle C D M N; after which, they will soon collapse and appear unelectrified; if now

* I once made an electrometer of this sort, which could continue to be electrified for above 12 hours, and that in a room without fire.

the wax is removed, they will again diverge, and remain electrified positively.

In this operation, the wax does not impart any of its Electricity to the electrometer, but only act by means of its atmosphere, *viz.* when the excited wax is first brought near the brass cap E F, (agreeable to the well-known law of Electricity, and according to Dr. FRANKLIN's hypothesis) it determines the electric fluid naturally belonging to the corks towards the cap; hence the corks repel each other. Now, if in this state they touch the sides of the glass C D M N, they acquire from it a quantity of electric fluid equal to that which, by the action of the excited wax, was driven towards the cap; consequently they collapse, and appear unelectrified. Notwithstanding this appearance, the cap is actually overcharged; so that when the wax is removed, the overplus of the electric fluid, which the corks had acquired from the glass and tin-foil stuck upon it, and which was crowded upon the cap, because of the negative atmosphere of the wax, now diffuses itself equally through the cap, the wires, the corks, &c. and therefore the

corks repel each other with positive Electricity.

If, instead of the sealing-wax excited negatively, an electric possessed of positive Electricity be used, the electrometer acquires the negative Electricity, and the explanation, *mutatis mutandis*, is the same as above.

By considering this remark it will appear, that when this electrometer is electrified either positively or negatively, and an electrified body be brought towards the brass cap, the Electricity of that body will be of the same kind with that of the electrometer if the corks increase their divergency; but it will be of the contrary kind if the corks approach one another.

When this instrument is to be used to try the Electricity of the fogs, the air, the clouds, &c. the observer is to do nothing more than to unscrew it from its case, and, holding it by the bottom A B, to present it to the open air, a little above his head, so that he may conveniently see the corks P, which will immediately diverge if there is any Electricity; whose nature, *i. e.* whether

ther positive or negative, may be ascertained by bringing an excited piece of sealing-wax, or other electric, towards the brass cap E F.

It is perhaps unnecessary to remark, that this observation must be made in an open place, as the roads out of town, the fields, the top of a house, &c.

In the roads between Islington and London, I have often made use of this instrument; by which I have confirmed the observations of THOMAS RONAYNE, Esq; who first discovered the Electricity of the fogs, as testified by a paper of his published in the Phil. Transactions; and who has remarked, that a fog is very rarely not electrified, but in frosty weather the air is constantly electrified.

Promiscuous Experiments.

Having had frequent occasion to observe how difficult it is to deprive sealing-wax of its Electricity entirely, after it has been well excited, I had the curiosity to try
whether

whether water could effect it ; in order to that, I tied a stick of sealing-wax to a silk string, about a yard long, and after having excited it very powerfully with flannel, I plunged it in a tin vessel full of water, and immediately drawing it out, brought a very sensible electrometer near it, and observed, that at first it shewed no sign of Electricity, but in about half a minute's time it manifested a small, but very sensible degree of negative Electricity. A glass tube treated in the same manner, was deprived of all its Electricity by the water.

I have often remarked, that after having excited a glass tube with the amalgamed rubber, in the usual manner, the part of it which had been under my hand, was negative. This minus state was still more conspicuous, when I grasped with my hand the part next above, *viz.* part of that which had been excited positively by rubbing. In the same manner, when I excite a stick of sealing-wax by rubbing it with flannel, I often find, that the part of it which I had held with my hand was in a contrary state of Electricity, *viz.* positive.

Being

Being desirous of trying the conducting power of the effluvia of burning bodies, in a manner more satisfactory than it had hitherto been done, I contrived an instrument for that purpose, which is represented in fig. 5 *. The handle of it A B, is a glass tube, into the extremity B of which, a wire E I, and a smaller glass tube B C, are cemented by means of sealing-wax. From the extremity of this small tube, another wire G F proceeds, which, as well as the wire E I, is bent at top, so that the extremities of both wires E F may be about one-tenth of an inch from one another. G H is a small wire, fastened to the wire F G, and to the extremity of the handle, so that when the instrument is held in one's hand, this wire touches the hand. K is a small cork-ball electrometer, which, when the instrument is to be used, is affixed to the pin D, which proceeds from the wire I E. When experiments are to be tried with this instrument, the electrometer K must be affixed to the pin D, and must be electrified so as the

* This fig. is half the real size of the instrument.

cork-balls may diverge as far as possible: this done, the extremities E F of the wires are brought within the effluvia that are to be tried, which, if they are of a good conducting nature, will complete the communication between the two wires E F, and discharge the electrometer of its Electricity; otherwise the electrometer will remain electrified for a considerable time. The experiments which I made with this instrument are neither numerous, nor so often repeated as to be depended upon; excepting one only, which perhaps it will not be useless to mention: I found that the fumes arising by the action of a lens from the amalgam of tin-foil and mercury, conducted so badly, that the electrometer lost its Electricity in a time very little less, than is required without any fumes whatever.

APPENDIX.

N^o I.

OF THE VINDICATING ELECTRICITY.

1. **A** B, *ab*, fig. 6, represents a plate of glass, coated on both sides with the two metallic coatings C D, *c d*, which are not stuck to the glass plate, but are only laid upon it.

From the upper coating C D, three silk threads proceed, which are united at their top H, by which the said coating may be removed from the plate in an insulated manner, and may be presented to an electrified electrometer, as represented in fig. 7, in order to examine its Electricity. F G is a glass stand, which insulates and supports the plate, &c.

2. Let

2. Let the plate A B, *ab*, be charged in the common manner, by means of an electrical machine, so that its surface A B may acquire one kind of Electricity, (which may be called K) and the opposite surface *ab* may acquire the contrary Electricity, (which we shall call L). Then, if the coating C D be removed from the plate, and be presented to an electrified electrometer, as represented in fig. 2. it will be found possessed of the Electricity K, *viz.* of the same kind with that which was communicated to the surface A B of the glass plate ; from whence it is deduced, that the surface A B has imparted some of its Electricity to the coating. Now, this disposition of the charged plate to give part of its Electricity to the coating, is what the learned F. BECCARIA nominates the *Negative vindicating Electricity*.

3. If the coating be again and again alternately laid upon the plate and removed, its Electricity K, will be found to decrease gradually, 'till after a number of times (which is greater or less, according as the edges of the plate insulate more or less

less exactly) the coating will not appear at all electrified. This state is called *the limit of the two contrary Electricities*; for if now the above-mentioned operation of coating and uncoating the plate be continued, the coating will be found possessed of the contrary Electricity, viz. the Electricity L. This Electricity L of the coating is weak on its first appearance, but it gradually grows stronger and stronger till a certain degree; then insensibly decreases, and continues decreasing until the glass plate has entirely lost every sign of Electricity.

By this change of Electricity in the coating, it is deduced, that the surface A B of the glass plate changes property; and whereas at first it was disposed to part with its Electricity, now (*viz. beyond the limit of the two contrary Electricities*) it seems to *vindicate* its own property, that is, to take from the coating some Electricity of the same kind with that of which it was charged: hence this disposition was by F. BECCARIA called the *Positive vindicating Electricity*.

4. This

4. This positive vindicating Electricity never changes, though the coating be touched every time it is removed. It appears stronger, and lasts a very considerable time after the plate has been discharged; which is a very surprising property of glass, and probably of all good and solid electrics.

5. If, soon after the discharge of the plate, the coating be alternately taken from the plate, and replaced, but with the following law, *viz.* that when the coating is upon the plate, both coatings be touched at the same time, and when the coating is off, this be either touched or not; then the surface A B of the plate, on being uncoated every time, takes a quantity of Electricity, which it alternately loses every time it is coated*.

6. On removing the coating in a dark room, a flash of light appears between it and the glass, which is still more conspi-

* This may be proved by touching an insulated electrometer with the coating, when this is standing upon the plate, and when separated from it.

cuous, if the coating be removed by the fingers being applied immediately to it, *viz.* not in an insulated manner ; because, when the coating is not insulated, the glass plate can give to, or receive from it, more of the electric fluid, and that more freely, than otherwise.

7. It is observable, that in the negative vindicating Electricity, the glass loses a greater or less portion of Electricity, in an inverse proportion of the charge given to the plate, *viz.* the part lost is greater when the charge has been the weaker ; for in the positive vindicating Electricity, the force of receiving Electricity is the stronger, when the charge has been stronger, and contrarywise.

8. If, after every time that the coating CD is removed, the atmospheres E, e, that is, the air contiguous to the surface of the glass plate, be examined, they will be found electrified as in the following table, *viz.* the threads of an electrometer, brought within one or two inches, or more, of the surfaces AB, ab, will diverge with Elec-

G g

tricities

tricitities contrary to those expressed in the table.

During the time of the negative vin- dicating Electricity	{	the air E,	{	moderately	{	moderately L
		if the plate		high - -		o
		has been		very high -		moderately K
		charged				

the air *e* is electrified L.

During the time of the positive vin- dicating Electricity	{	the air E	{	are electrified L.
		The air <i>e</i>		

9. Although we are not acquainted with the cause of vindicating Electricity, any farther than to consider it as a disposition or property of charged glass, yet the phenomena of the Electricities of the air, contiguous to the surfaces of the plate, seem to be a proper consequence of Dr. FRANKLIN's theory of Electricity, and are accountable by it; for it is a well-known principle of that theory, that when one side of a coated electric, fit to receive a charge, acquires a greater quantity of Electricity than the opposite side can acquire of the contrary Electricity, then both sides of that electric appear possessed of the same kind of Electricity, namely, of that communicated

municated to the first-mentioned side. Now, when in the negative vindicating Electricity, the surface *A B* of the glass plate gives part of its Electricity to the coating, then the other side *ab*, being more electrified *L*, than the side *A B* is electrified *K*, it is plain that, according to the said principle, both sides must appear electrified *L*. But in the positive vindicating Electricity, the side *A B* of the glass plate receives some Electricity of the kind *K* from the coating, therefore both sides must affect the air with the Electricity *K*.

10. There remains only to be explained the reason why, when the plate has received a high charge, the air *E*, during the time of the negative vindicating Electricity, appears electrified *K*, whilst the air *e* is electrified *L*. In order to render this explanation more intelligible, let us suppose the glass plate to have been electrified positively on the side *A B*; then, in the negative vindicating Electricity, the surface *A B*, on being uncoated, loses a part of its Electricity, which is so much the greater as the charge has been the less (§ 7.);

therefore, when the charge has been moderate, *A B* loses a greater portion of electric fluid, than that with which the air *e* can supply the surface *ab*; hence the surface *ab* will remain more negatively electrified than the surface *A B* is positively; consequently, according to the above-mentioned principle, (§ 9.) both the atmospheres *E*, *e*, must appear in a negative state when the charge has been a certain degree higher; then the surface *A B*, on being uncoated, loses just so much of the electric fluid as the air *e* can give to *ab*, therefore the air will not appear electrified. But when the charge has been very high, *A B* loses a less portion of electric fluid than the air *e* can give to *ab*; therefore *e*, by having given some of its natural electric fluid to *ab*, will appear negative, and *E* will appear positive in a small degree. If the plate be supposed to have been charged negatively on the side *A B*, the explanation of the phenomena is the same, changing only the name of positive Electricity into negative, &c.

11. This property of charged glass, called vindicating Electricity, is observable also

also when two glass plates, laid one over the other, and coated on their outward surfaces only, are charged jointly like one plate. Suppose A B, C D, fig. 8, to represent the two plates charged together, *viz.* by having presented the coating F to the prime Conductor, and having at the same time connected the coating G with the ground, in which state, it is easy to conceive, that the upper surface of the plate A B would be positive, its under surface would be negative, the upper surface of the plate C D, *viz.* the surface contiguous to the plate A B, would be positive, and its opposite surface G would be negative. Now if these plates, after having been charged, be alternately separated and joined, without ever touching their coatings, it is plain that their surfaces, contiguous to one another, whenever the plates are separated, will uncoat each other, consequently the phenomena of vindicating Electricity will take place, that is, each of the inside or naked surfaces, when the plates are first separated, will lose part of its Electricity. This lost Electricity gradually decreases till it vanishes, after which period,

each of the said surfaces will gradually recover part of its lost Electricity, &c.

12. By the principle noticed above, (§ 9.) when one surface of either plate has acquired a quantity of one kind of Electricity more than the opposite surface has acquired of the other, then both surfaces of that plate must appear possessed of that and the same kind of Electricity; hence it follows, that when the plates A B, C D, are at first separated for a certain number of times, *i. e.* during the negative vindicating Electricity, the plate A B must appear positive on both sides, and the plate C D negative on both sides; but after the *limit of the two contrary Electricities*, when the positive vindicating Electricity has taken place, then the plate A B will appear negative on both sides, and the plate C D positive on both sides.

13. The adherence of the plates to one another keeps pace with the vindicating Electricity; so that it is very strong at first, but gradually decreases with the negative vindicating Electricity, till it becomes insensible;

senfible; but after the limit of the two contrary Electricities it appears again, and then it increases and decreases with the positive vindicating Electricity.

14. Every other particular relating to the phenomena of vindicating Electricity, exhibited with one plate, does also take place in the experiment with two plates; except the phenomena considered above (§ 10.), which the two plates cannot exhibit, on account that they are not capable of receiving a very high charge, as a single plate is; which high charge is absolutely necessary to produce that appearance.

N^o II.OBSERVATIONS UPON THE CONDUCTORS
OF LIGHTNING.

SINCE the publication of the First Edition of this Treatise, it happened that a house belonging to the Board of Ordnance, at Purfleet, was struck by lightning, though furnished with a Conductor. This accident excited anew the controversy relating to the construction of Conductors to secure houses from the effects of lightning, especially relating to their termination; and various experiments were made by very able Electricians, in order to decide the controverted point. Mr. B. WILSON and Mr. ED. NAIRNE, both members of the Royal Society, were the principal actors in this experimental investigation; the former giving constantly the preference to short conductors terminating in a ball, and the latter preferring long Conductors acutely pointed; which has been and is the prevailing opinion with almost

almost all the principal Electricians in England, as well as abroad ; beginning from the first inventor of those Conductors (the great philosopher Doctor FRANKLIN). Mr. WILSON, the principal and almost the sole opponent of the Franklinian construction of Conductors, exhibited some ingenious electrical experiments upon a large scale ; which threw great light upon the property of points in respect to Electricity, and seem at first sight to decide the question in favour of knobbed Conductors, as will appear by the following pages. On the other side, Mr. NAIRNE performed some well-imagined experiments, which seem to establish, beyond any doubt, the prevailing opinion in favour of pointed Conductors ; which was afterwards still more confirmed and elucidated by Lord MAHON, in his learned work, entitled, *Principles of Electricity*, and published in the year 1779.

Notwithstanding those various disquisitions, and new observations, it seems that what I had previously wrote, relating to the construction of Conductors, did not require any material alteration ; hence I thought proper to reprint, in this Second Edition,

Edition, exactly that which had been advanced relating to Conductors of lightning in my first publication ; and have reserved for this dissertation, to make mention of those additional remarks, which, in the present more advanced state of the science, are necessary to be noticed. Mr. WILSON, Mr. NAIRNE, and others, must excuse my giving a very short and summary account of their valuable experiments, since the limits of this work are by far too short to admit a full account of their observations. I shall just mention the principal facts ascertained, so as to make evident the deduction which naturally follows them, and which is necessary to establish the present improved theory of Conductors ; omitting those remarks which seem to be not essential, and even dispensing with the particular description of the various apparatuses used for this purpose. The *Board-house*, struck by lightning on the 12th of May 1777, had a pointed iron spike, which projected ten feet above the middlemost and highest part of its roof, and which had a continued metallic communication to the ground. The lightning did no other
I damage

damage to his house, than to throw down a few stones from one of its upper corners, which were next to two iron cramps; which cramps had not a metallic communication with the Conductor. This corner was forty-six feet distant from the top of the Conductor. In this case it is difficult to say, whether the lightning struck the Conductor first, or the corner of the house just over the above-mentioned iron cramps, and from thence, being passed to the metal which communicated with the Conductor, was conducted to the ground, without causing any farther damage to the house. In the first case, the point of the Conductor would, in all probability, have been fused, as is generally the case; but no mark of fusion could be perceived on it. The second case seems not very likely to have happened, since the Conductor was far above the corner that was struck, and since the lightning is known to strike the most elevated objects, and those which have a better communication with the earth, in preference to any other *. In any case, the

* Mr. NAIRNE terminates the account of his above-mentioned experiments with the following passage:

“ I must

the only useful remark that can be drawn from this accident is, that all the metallic parts, that are in a building, should be connected with the Conductor, otherwise it is not unlikely, but that, either by a direct stroke, or by a lateral explosion, the house may suffer some damage from lightning. Mr. WILSON, who had formerly declared his opinion against elevated and pointed Conductors, derived from this accident a strong proof apparently in favour of his theory,

“ I must beg to intrude a little more on your time,
 “ to remark on that part of Mr. WILSON’s paper,
 “ where, from his experiments, he seems to conclude,
 “ that the lightning at Purfleet first struck on the
 “ point of the rod of the Conductor, and then, by a
 “ lateral part of that stroke, struck the cramp on the
 “ coping-stone. I believe, if he had examined the
 “ situation of the stone, and the place where the
 “ cramp was struck, he would have found, that, if
 “ the lightning had struck on the point of the Con-
 “ ductor, that, to have produced that effect on the
 “ stone, it must, after it had struck on the point,
 “ and passed down a quantity, have struck from the
 “ metal up into the air, then down again on the
 “ cramp, and then again to the metal it had left; for
 “ the small dent or hollow made by the lightning was
 “ on the upper surface of the stone, and yet the metal-
 “ lic communication to the earth continued from
 “ the

theory, and soon sat about performing several experiments, in which the natural accident was imitated by art *. Mr. WILSON's great apparatus was fixed in the Pantheon, Oxford-street. It consisted principally of the following parts:—A cylinder, 16 inches in diameter, and 155 feet long, covered with tin-foil, formed the prime Conductor, which was charged by a good electrical machine of the common sort. This vast Conductor was suspended by various silk strings, at a convenient distance

“ the point under the stone which was struck. It
“ appears more probable to me, from the trifling
“ damage it did, that the charged cloud had passed
“ over the pointed Conductor, and had been ex-
“ hausted of a great part of its Electricity in passing ;
“ and that, after it had passed, it was attracted down
“ lower by a ridge of hills that was beyond, and that
“ the cloud being out of the influence of the point to
“ prevent its striking, the end of the cloud might
“ strike at an angle in the cramp, and so to the metal-
“ lic part of the Conductor, which was only about
“ 7 inches below. I shall conclude with observing,
“ that Mr. HENLY and myself had the pointed rod
“ of the Conductor at Purfleet taken down to ex-
“ amine the point ; but we found no appearance on it
“ that shewed that it had been struck.”

* The account of those experiments is inserted in the 68th vol. of the Phil. Transf.

from the floor and walls. To this Conductor there was added a wire 4800 feet long, which was also supported by silk strings, and, on account of its prodigious length, was bent in a great many places, going backwards and forwards in various directions. Sometimes this wire was separated from the great cylinder; but, for the generality of experiments, they were made to communicate together, so as to form one extensive Conductor.—By means of a proper frame and machinery, a wooden model of the above-mentioned house, that was struck by lightning, was made to pass with different required degrees of velocity under and across one end of the great cylinder. This model was furnished with a Conductor at top, which was sometimes terminated in a point, and at other times ended in a ball, but which was made to communicate with the earth by as good a metallic communication as can be desired by the most scrupulous experimentator. Whilst the model of the house was kept at a proper distance from the great cylinder, and after a known number of turns of the wheel, the model being let go, passed under
the

the end of the cylinder with any required velocity, and at the moment that passed immediately under the charged cylinder, it received the stroke from it upon its Conductor, &c. Now, the principal experiments which Mr. WILSON made with this apparatus, are briefly expressed in the following articles :

1. When the model was furnished with a sharp Conductor, on being made to pass under the charged cylinder, it drew off a good deal of the electric fluid from it in a silent manner, and that absorption, as it may be said, began long before the model came quite under the cylinder, as was shewn by the appearance of light, &c. The charge which afterwards remained in the cylinder was inconsiderable: all which shews the tendency that a point has to draw the electric fluid silently, and from a distance.

2. If, instead of a point, the model was furnished with a knobbed Conductor of the same length with the pointed one, the quantity of electric fluid drawn off in repeating

peating the above experiment was not so considerable as before, and it was almost nothing, if the knobbed Conductor was much shorter than the pointed one, as could have been expected.

3. When the model with the sharp Conductor was made to pass under the cylinder fully charged, the pointed Conductor was generally struck with a full and strong explosion; whereas, if the Conductor was terminated in a ball (though of an equal length with the pointed Conductor, and consequently equally distant from the cylinder when the model was just under it) it was not struck, the cylinder remaining charged, &c.

4. “ The weight which moved the model in the preceding experiment, was gradually reduced till it was nearly balanced by the friction; and when the motion was rendered so slow as seven feet seven inches in seven seconds, it was very little accelerated; and in this state the great cylinder being charged, the model was suffered to pass; and, though

“ though the velocity was less than three
“ quarters of a mile in an hour, the point
“ was struck.”

The intelligent reader may remark, that by the above-mentioned observations, the already-known properties of points were clearly shewn; that the very reasons before advanced by various philosophers, for preferring pointed Conductors of lightning to such as are blunted, were confirmed; but, however, that one remarkable observation, which could have been hardly believed before, was established, *viz.* that a point in those circumstances could receive so full a stroke, as we have mentioned above. Indeed this is a very good observation of Mr. WILSON, and a most plausible argument in favour of his opinion relating to the construction of the Conductors of lightning. Hence he expatiates upon the danger of those houses, which are furnished with elevated and pointed Conductors; and absolutely recommends knobbed conductors, which are either even with, or rather a little shorter than the top of a building; since, says he,

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the

the pointed Conductors invite the lightning. It is almost superfluous to remark, that it is for that very property, that elevated and pointed Conductors are preferable to knobbed ones, *viz.* because they attract the matter of lightning from a greater distance: hence they may defend a greater extent of building; hence, by drawing a considerable quantity of electric fluid from the clouds, when at a distance, so as to lessen their charge, they may thus actually avoid a full explosion; the intention of putting a Conductor to a house, being to defend the house from the bad effects of lightning, and not the Conductor itself from attracting the matter of or being struck by the lightning.—When the Conductor of a house is struck, the only damage it can receive in that case, it seems, can only arise from a lateral explosion between the Conductor and other pieces of metal, or other very good Conductors, which are contained in the house, and are not properly connected with the Conductor. For this reason, it is proper to connect with the Conductor, by a metallic communication, all the pieces of metal,
and

and indeed other good Conductors, as a cistern of water, &c. that are in a house, especially those which are near the outside, and the top of it. This, however, is almost impossible to be done perfectly; but then those lateral effects are not of so very dangerous a nature, excepting indeed when the building contains substances of a very combustible quality, as gun-powder, &c. in which case, the most scrupulous attention is hardly sufficient to prevent any bad accident. Notwithstanding the obviousness of the above-mentioned remarks, Mr. WILSON's experiments determined several persons in favour of the knobbed Conductors: hence Mr. NAIRNE undertook to oppose Mr. WILSON's theory with a clear and convincing set of experiments. The prime Conductor used by Mr. NAIRNE was one foot in diameter, and six feet long, consequently by far smaller than that used by Mr. WILSON. The other apparatus was different, and the electrical machine was much more powerful than that used by Mr. WILSON*. But with

* See Mr. NAIRNE's account of those Experiments, &c. in the 68th vol. of the Phil. Transf.

this apparatus he amply shows the properties of points and knobs, with respect to Electricity; and, different from Mr. WILSON, shows, that in many experiments, and under various circumstances, a knob is struck in preference to a point. This diversity of appearances, and results of experiments, in cases seemingly alike, will at first sight be thought a contradiction; but, when duly considered, the different phenomena may be all reconciled to a few very simple and natural propositions: *viz.* 1. A point draws the electric fluid from an electrified body, from a much greater distance than a blunt-terminated body; but the quantity must be limited, and subject to be altered by many causes; such are, the degree of condensation of the electric fluid upon the electrified body; the time given to the point; the acuteness of the said point; its free or encumbered situation; its perfect or imperfect communication with the earth, &c. Thus, if the pointed body be not made to communicate with the earth, but the communication be interrupted by a short interval, then, on presenting a body sufficiently charged with electric fluid, to
the

the said point, a full spark will go from the former to the latter, because the point, on account of the interruption of communication, cannot discharge to the earth, or other fit body, the electric fluid by little and little, consequently cannot receive it silently from the electrified body to which it is exposed, but can attract only that quantity which can leap between the interruption, and which passes in the form of a spark. Thus also, if the point is suddenly brought within a sufficient distance of a strongly-electrified body, it will receive a spark, because a sufficient time was not allowed it to draw off the electric fluid silently, as would happen if the point was gradually brought near. After the same manner, the ingenious reader may imagine a great multiplicity of cases, in which a point may be struck or not struck by an electrified body; hence is derived the apparent contradiction between the experiments of Mr. HENLY, Mr. WILSON, Mr. NAIRNE, and various others: but it always remains true, that a pointed or sharp-edged body draws the electric fluid from a greater distance than those

bodies which are blunt or more obtuse, all the other circumstances being the same in both cases.

Lord MAHON, in his above-mentioned work, shews a property of electric atmospheres, which he calls the *returning stroke*, and which he is of opinion that can occasion great damage in some cases. This is that quantity of electric fluid, which, by the vicinity of a cloud highly electrified, is driven away from certain bodies, and which suddenly returns to those bodies when the cloud happens to discharge its Electricity by a stroke of lightning to any other body; for then the atmosphere which kept off the electric fluid of the bodies that were within its action, ceases at once. Our noble author shews experimentally, that such a returning stroke may occasion great damage, even at a good distance from the place where the stroke of lightning happens, and that its effects may be very considerable; all which confirms the already-made observation, *viz.* that all the best and largest conducting bodies that are in a house, should be connected with
the

the Conductor of lightning. Without detaining my reader with further disquisitions, I shall only take notice of the most notable particulars that should be kept in view, and should be considered as the leading principles in erecting Conductors for the lightning; and shall then conclude with the *requisites necessary* for the proper construction of Conductors, which requisites I shall transcribe exactly from Lord MAHON's work.

A pointed body attracts the matter of lightning more or less easily, according as it is more or less acute; according as it is less or more encumbered by surrounding bodies; or as it is more or less elevated, and as its communication with the earth, by means of conducting bodies, is more or less perfect. The clouds are bad Conductors, and in general the electric fluid is not highly concentrated on them in proportion to their extent; they are often separated from each other; they may come towards a Conductor or a house in every direction; and move with various velocities at different times. The pointed Conductor that is

erected in order to transmit the lightning with safety to the ground, can only defend a limited extent of building, the quantity of which varies according to many circumstances. In cases of powder-magazines, and such-like very combustible substances, great damage may be occasioned by a lateral explosion or returning stroke, if the Conductor happened to be struck; which may be only avoided by making a proper communication between all the substances of a good conducting nature that are in the building.

In consequence of all those observations, and various others mentioned in the course of this book, it seems proper to have in view the following instructions, in erecting Conductors for the lightning.

1. "That the *rods* be made of such substances as are, in their nature, the best *Conductors* of Electricity."

2. "That the rods be *uninterrupted*, and *perfectly continuous*."

3. "That they be of a *sufficient thickness*."

4. "That

4. " That they be perfectly *connected* with the *common-stock*."

5. " That the upper extremity of the rods be as *acutely pointed* as possible."

6. " That it be *very finely tapered*."

7. " That it be *prominent*."

8. " That each rod be carried, in the *shortest convenient direction*, from the point at its upper end, to the *common-stock*."

9. " That there be neither *large* nor *prominent* bodies of metal upon the top of the building proposed to be secured, but such as are *connected with the Conductor* by some proper metallic communication."

10. " That there be a sufficient *number* of high and pointed rods: And,

11. " That every part of the rods be *very substantially* erected."

N^o III.

EXTRACT OF A LETTER FROM MR. ARDEN, LECTURER IN NATURAL PHILOSOPHY, DATED SEPTEMBER 25, 1772.

“ ABOUT fourteen or fifteen years ago, in the presence of W^m. CONSTABLE, Esq; at his seat at Burton Constable, in Holderness, I made the following experiments :

“ I placed a large coated jar, that would hold three or four gallons, directly under the prime Conductor of a very good electrical machine. The prime Conductor was at least eight or ten inches above the top of the jar, and the communication was made by a brass wire, bent at one end over the prime Conductor, and the other end passed through a small glass tube (contrived by Mr. CONSTABLE to prevent the electric matter from easily flying off) was suspended in the middle of the jar, and had a small piece of brass chain fastened to it, that rested on the bottom of the jar.

“ I then began to turn the wheel, and, after turning about 100 or 150 times, as low in the jar as I could see for the coating, I perceived a ball of fire, much resembling a red-hot iron bullet, and full three quarters of an inch in diameter, turning round upon its axis, and ascending up the glass tube that contained the brass wire, which was the Conductor to the inside of the jar.

“ I immediately asked Mr. CONSTABLE, if he saw the ball of fire? he said, Certainly. I said, I will turn on. He answered, By all means. I kept turning the wheel, and the ball of fire continued turning upon its axis, and ascending up the glass tube till it got quite upon the top of the prime Conductor. There it turned upon its axis some little time, and then gradually descended, turning upon its axis as it had done in its ascent, and so continued till it was so much below the top of the coating that we could no longer see it. But soon after this, a very great flash was seen; a large explosion was heard, and strong smell of sulphur was perceived all over the room; a round aperture was cut through the side of
of

of the jar, as fine as if it had been cut with a diamond, rather more than three quarters of an inch in diameter, and between two and three inches below the top of the coating, and the coating was torn off all round the aperture, about three or four inches in diameter. The jar was a pretty strong one, of crown glass.

“ I then took another jar, so like the first, that when both were whole I could not easily perceive any difference between them. I then attempted to charge this jar, in the same manner as the other, and we both observed it very accurately. No ball of fire was seen, but presently the jar discharged itself with a great flash and explosion, and at about the same part as of the first jar; but instead of the aperture which was made in the first jar, there was a circle about three quarters of an inch diameter, as white as chalk, and the coating torn off round about it as before. Upon touching the white part, it dropped out, and appeared to be glass in a fine powder.

“ We

“ We broke several other different-sized jars that day, (which made Mr. CONSTABLE say we were in great luck), but without any thing else remarkable.

“ The first experiment was made soon in the afternoon of a clear day, and the machine stood directly between us and a window, which was not above a yard from it. I don't hear that this ball of fire has been produced by art by any one else, to this day, although it is often produced by nature.

“ I had the pleasure of seeing Mr. CONSTABLE this day, and of reading the account of these experiments to him, and, to the best of his memory, he thought the whole was strictly true.

“ Mr. CONSTABLE thinks it would not be difficult to repeat the experiment, and to produce the ball of fire at any time, provided the jar is large, and not coated too near the top, and that the wire communicating from the prime Conductor to the inside of the jar is made to pass through a small

small glass tube, (which is certainly of great advantage in making experiments of this kind) and that the machine acts very strong. If not, it will be in vain to attempt it."

AFTER this letter, Dr. PRIESTLEY, out of whose works it has been transcribed, subjoins the following remarks * :—" The fact mentioned in the preceding letter is of a very remarkable nature, and, being perfectly well ascertained, it is of importance that it be generally known, and kept in view. For though no person, that has hitherto been made acquainted with it, has been able to repeat the experiment, others may be more fortunate. Dr. FRANKLIN, and, if I mistake not, Mr. CANTON also, and myself, were present when Mr. HENLY endeavoured to produce this appearance; but, though every expedient that any of us could suggest was made use of, we had no success, and I have several times attempted it in vain since. I shall not, however, desist from my attempts.

* Experiments on Air, &c. vol. v.

“ Mr.

“ Mr. ARDEN's own evidence is abundantly sufficient to authenticate the fact, and I have since had from Mr. CONSTABLE himself the same account of it. Could we repeat this experiment, there would not, I think, be any natural phenomenon, in which the electric fluid is concerned, that we could not imitate at pleasure. This circumstance alone makes it a very interesting object of investigation.”

N^o IV.OBSERVATIONS CONCERNING SOME PRO-
PERTIES OF THE ELECTRIC FLUID.

AMONGST the various experiments performed by Mr. WILSON in the Pantheon, as mentioned in the preceding pages, he made some with a long wire, which was suspended by silk lines, and went in various directions through that great building. This wire was 4800 feet long, and $\frac{1}{2}$ of an inch in diameter. It consisted of many pieces, which were connected by twisting the several ends together. — Mr. WILSON electrified this extended wire by means of an electrical machine situated next to one of its extremities; and when the wire was fully charged, which happened after a few turns of the wheel, a person discharged it, by presenting his hand to it, which was attended with a short spark, but with a very disagreeable strong shock. Then Mr. WILSON took an equal length of wire, of the same diameter

ameter with the above-mentioned extended one, and, putting it all coiled together upon a glass stand, charged it with electric fluid, by means of the same machine, and when this wire was fully charged, which took place after about half a turn of the wheel, a spark was taken from it, but which occasioned a sensation by no means comparable with that given by the extended wire, since this, though longer than the spark of the extended wire, was hardly to be felt, whereas that was remarkably strong.

The explanation of those effects might easily occur to a person little versed in Electricity. The extended wire acquired a much greater quantity of Electricity than that which was coiled up, for the same reason for which an extended piece of tin-foil, twenty square feet wide, and which weighs one pound, can acquire incomparably more Electricity than a solid ball of tin, which weighs one pound also; namely, because the extended wire exposes a far greater surface to the free air, than the wire that is coiled up; and the spark given by

the coiled wire is longer than that given by the other, in so much as the electric fluid, whatever its quantity may be, can be much more condensed on the coiled than on the extended wire ; it being well known, that the length of the spark given by electrified Conductors is proportional to the condensation, and not to the quantity of electric fluid.

To observe, that the extended wire required many turns of the wheel before it became charged, whereas the coiled wire required less than one turn ; the observations made and mentioned by various writers on Electricity, relating to the capacity of Conductors under various circumstances ; Dr. FRANKLIN's experiment of the *can* and *chain*, and innumerable other experiments of the like nature, might have convinced Mr. WILSON of the truth of the above-mentioned natural and clear explanation ; but, upon those phenomena Mr. WILSON establishes a principle which does not seem satisfactory. He imagined, that in so much the extended wire gave a much stronger shock than that which was
coiled

coiled up, as the electric fluid percurring the whole length of the extended wire acquired a great degree of velocity; hence the impetus with which it struck the hand or other body presented to the charged wire, occasioned that disagreeable sensation, which sensation was not accompanied with the spark given by the coiled wire, because the electric fluid could not acquire any velocity, as it did not go through a great extent of conducting substance.

This theory seems to be not true, for the following reasons. First, It is well known that metal, and in general any sort of conducting substance, does in some measure resist the free passage of the electric fluid through its substance; hence the electric fluid, in going through a long Conductor, must be retarded rather than accelerated. Secondly, The electric fluid being elastic, whenever a way is open for it to escape out of a Conductor, upon which it has been confined, it must exert its greatest force at first; that is, the quantity of it, which comes out at first, has the greatest velocity, because it is impelled by the greatest expansive force;

force ; but, according as more and more of the electric fluid comes out of the Conductor, that impelling force or elasticity lessens ; hence the last particles of electric fluid come out of the Conductor with less velocity ; thus in a condensing fountain, out of which the stream of water issues, on account of the elasticity of the air condensed in the cavity of the instrument, the stream at first comes out with greater violence, and mounts higher up, but afterwards loses its velocity by degrees, because the condensed air becomes gradually less and less condensed, and consequently exerts a force continually smaller and smaller against the water. Lastly, It may be observed in general, as it has been proved by many experiments, that if two unequal Conductors, one of which A is more extended than the other B, discharge equal quantities of electric fluid under the form of sparks from like terminations, the spark given by A is less strong than the spark given by B, and that for the above-mentioned reasons.

Notwithstanding

Notwithstanding the obviousness of those remarks, Mr. WILSON, since he first made the experiments at the Pantheon, seems to have become continually more and more attached to his opinion, so that about two years ago, he published a small tract, entitled *A short View of Electricity*, in which he endeavours to establish his theory of the acceleration of the electric fluid, &c. upon mathematical principles. This step determined me to take notice of it in this Appendix, in order to prevent any wrong notions in the heads of novices; for persons who are not conversant with mathematics, will take any proposition for true, when they are assured that it is mathematically so. Mr. WILSON's theorem conceals a fallacy, and shews that a person very well skilled in a science, as Mr. WILSON is in Electricity, can easily fall into a mistake, when he is too much attached to a favourite opinion.—Mr. WILSON's words are as follow :

“ *Upon Acceleration.*

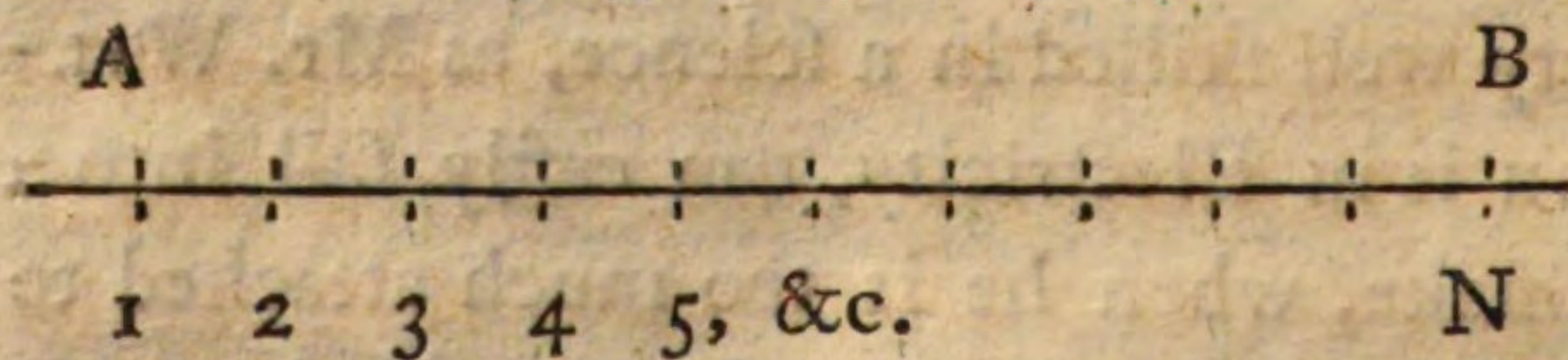
“ The experiments at the *Pantheon*,
“ which were intended to shew the accele-

“ ration of the fluid, having been objected
 “ to by many, who have not sufficiently
 “ attended to the known properties of the
 “ elastic fluid, it has been thought proper
 “ here to establish this very material point
 “ upon mathematical principles, with a
 “ view to put an end to all farther dis-
 “ putes on the subject.

“ But before this is done, it may be
 “ necessary to mention a material fact that
 “ was omitted in the account of those ex-
 “ periments ; which is this,

“ The shock received at the *middle* of
 “ the long wire, was *considerably* less than
 “ that which was received at either end.

“ T H E O R E M.



“ Let A B represent a cylinder of a
 “ given diameter, and suppose this cylin-
 “ der charged with the electric fluid. I
 “ say, if all the particles of this fluid are
 “ moved at the same instant towards A,
 “ the

“ the effect produced by the shock of this
 “ fluid at A will be nearly proportional
 “ to the square of A B ; for the total ef-
 “ fect at A is equal to the sum of the ef-
 “ fect of each particle contained in the
 “ cylinder A B : and the effect of each
 “ particle being proportional to its velo-
 “ city, the total effect at A will be propor-
 “ tional to the sum of all the velocities.
 “ But since the fluid is supposed nearly
 “ perfectly elastic, all the particles will
 “ arrive at A nearly at the same instant ;
 “ then the velocity of each particle will
 “ be proportional to the distance from the
 “ place it sets out, and the total effect at
 “ A will be proportional to the sum of all
 “ those distances.

“ But all those distances are expressed
 “ by the following numbers, 1, 2, 3, 4, 5,
 “ &c. - - - - - N (N expressing the
 “ length A B) in an arithmetical progres-
 “ sion. Then the sum of all the distances
 “ will be expressed by the sum of the
 “ arithmetical progression 1, 2, 3, 4, 5,
 “ &c. - - - - - N, and the effect at A

“ will be proportional to this sum, that is
 “ to say, to N^2 or AB^2 . Q. E. D.”

Mr. WILSON's abstract proposition is certainly evident, *viz.* “ That if all the particles of the electric fluid are moved at the same instant towards A, (by which, I suppose, he means if they arrive at A in the same instant of time) the effect produced by the shock of this fluid at A will be nearly proportional to the square of A B.” But this proposition cannot be possibly applied to the matter of fact, or actual experiment, since the condition upon which the proposition depends cannot be verified; *viz.* we do not know whether or no the particles of the electric fluid that are in the long wire, do all arrive at one end of it precisely at the same time. Besides, we may safely say, that from the considerations mentioned in the preceding pages, and from the analogy of other natural phenomena, it appears that they do not, and cannot arrive to the extremity of the wire precisely at the same time. Between the particles of electric fluid which arrive first at one extremity of the wire, and those which ar-

rive last at the same extremity, there is an interval, a difference of time. Mr. WILSON says, “all the particles will arrive at A, *nearly* at the same instant.” Now, even that *nearly* implies a length of time, which, however imperceptible it may be to our senses, is yet sufficient for the natural operation. For instance, suppose that the extended and electrified wire is a mile long, and also suppose that a quantity of electric fluid employs one hundredth part of a second of time to percur that length of wire, and that without acceleration, or even with a little retardation, which is by no means an exaggerated supposition. Now, if a way be opened to the electric fluid in the wire, *viz.* the hand, &c. be presented to one extremity of it, the nearest particles of the electric fluid will come out first, and the remotest last; yet that difference, agreeably to the supposition, does not exceed one hundredth part of a second, which is absolutely unperceivable by our senses; so that the appearance is exactly the same as if all the particles of the electric fluid came out of the extremity of the wire precisely at the same instant of time. I think,

think, therefore, that what Mr. WILSON imagines to have established upon mathematical principles, is far from being mathematically demonstrable. Without dwelling any longer upon Mr WILSON's proposition, and the corollaries which he deduces from it, I shall only take notice of a remarkable experiment he made at the Pantheon, with the already-mentioned apparatus; which, however, he attributes to the accumulated velocity, which the electric fluid acquired in percurring the substance of a very long Conductor.

Mr. WILSON fired gun-powder by means of the stream of electric fluid, but without spark or shock. The method is as follows, in his own words: " Upon a staff
" of baked wood a stem of brass was fixed,
" which terminated in an iron point at the
" top. This point was put into the end
" of a small tube of Indian paper, made
" somewhat in the form of a cartridge,
" about two-tenths of an inch in diameter.
" When this cartridge was filled with
" common gun-powder, (unbruised) the
" wire of communication with the well
" was

“ was then fastened to the bottom of the
 “ brass stem. Being so circumstanced, and
 “ whilst the charge in the great cylinder
 “ and wire was continually kept up by
 “ the motion of the wheel, the top of the
 “ cartridge was brought so near to the
 “ drums as frequently to touch the metal.
 “ In this situation, a small, faint, lumi-
 “ nous stream was observed between the
 “ top of the cartridge and the metal
 “ drum.

“ Sometimes this stream would set fire
 “ to the gun-powder at the instant of the
 “ application ; at others, it would require
 “ half a minute, or more, before it took
 “ effect. But this difference in time
 “ might probably arise from some differ-
 “ ence in the circumstances ; for any the
 “ least moisture, &c.”

It seems that in this experiment the gun-
 powder was fired by the heat occasioned
 by the dense stream issuing out of the vast
 Conductor, which discharged a prodigious
 quantity of electric fluid in that concen-
 trated manner. This experiment was af-
 terwards

terwards imitated by Mr. NAIRNE, with the Leyden phial. When a large electric jar was charged, Mr. NAIRNE presented the cartridge of gun-powder, similar to that used by Mr. WILSON, to the knob of the jar, and the powder was fired without any explosion of the jar. In this experiment, the wire upon which the cartridge was fixed, did not communicate with the outside of the jar by a good conducting communication, but both the outside of the jar, and the said wire, did communicate with the ground; so that it may be said, that the circuit between the two sides of the jar was imperfect; hence the discharge was not made by a full explosion.

I shall lastly conclude this work, with just mentioning some very remarkable improvements lately made by Mr. VOLTA, an account of which he has sent to the Royal Society. — This great philosopher has advanced the science of Electricity a good step beyond what was known a year or two ago, since he has found the means of discovering exceedingly small degrees of Electricity, and such as are not perceivable
by

by any other method already known. Mr. VOLTA observes, that when a metal plate, belonging to his electrophorus, is charged with Electricity, if it be laid flat upon an imperfect Conductor, as for instance, upon a very dry piece of wood, a dry marble slab, an oil-cloth, &c. it will preserve the Electricity for an incomparably longer time than if it were kept insulated in the air; and farther, that it will preserve the Electricity, even if it be touched several times with the finger, or other insulated Conductor, whilst it stands upon the imperfect Conductor; so that if afterwards it be taken up by its glass handle, it will still give a sensible spark.—If the said metal plate, or other conducting body, instead of being laid flat, be made to touch the imperfectly-conducting plane edgeways, the Electricity is immediately lost.—If the imperfectly-conducting plane be insulated, the electrified metal plate that is laid upon it will not preserve the Electricity nearly so long as when the said plane is not insulated.

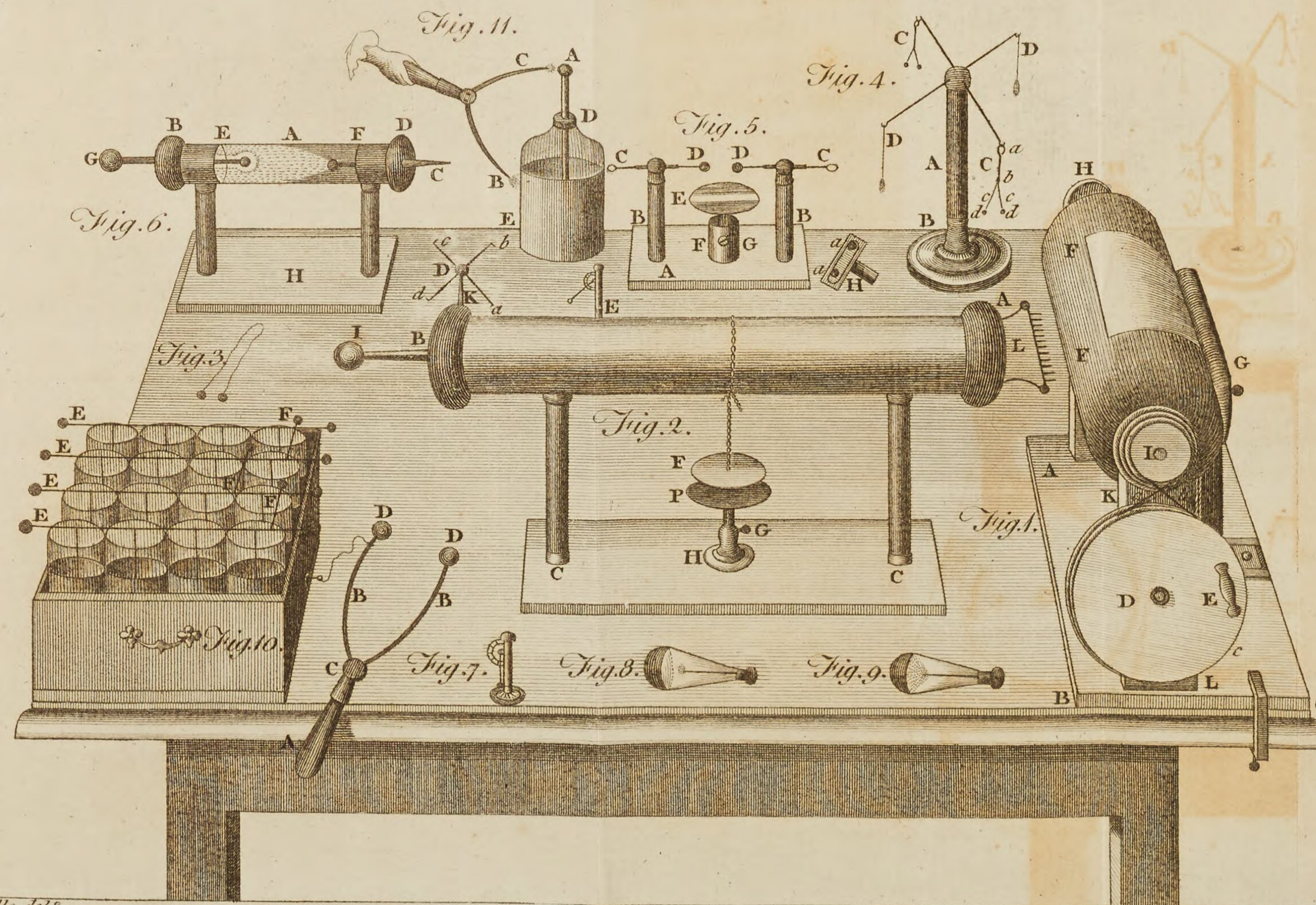
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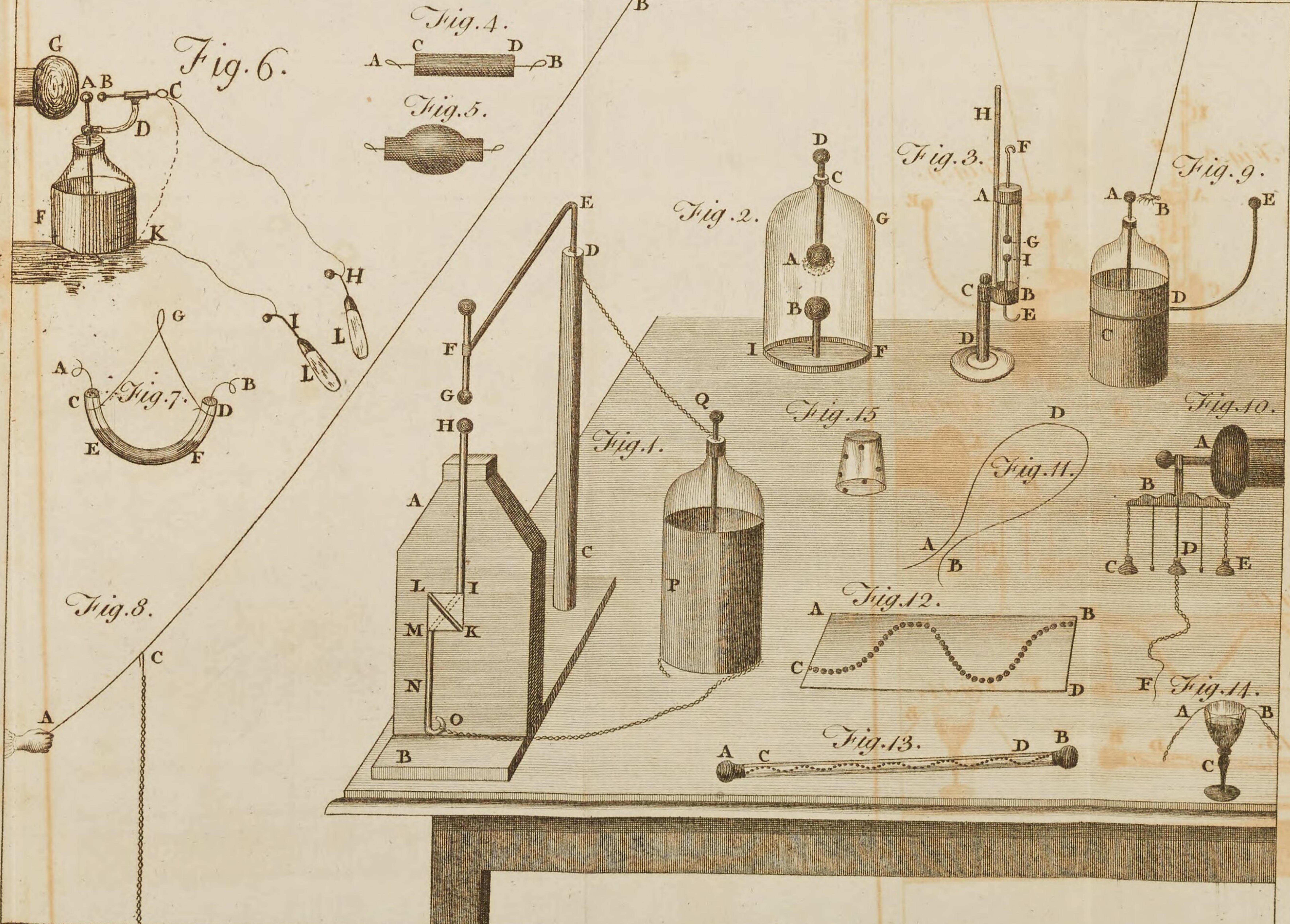
A metal plate, by being laid flat upon an imperfect Conductor, is not only enabled to retain its Electricity much longer than when insulated in the most perfect manner, but it does also acquire the property of receiving Electricity from such bodies, which either for their imperfect electric nature, or for the smallness of their size, could not communicate to it any sensible degree of electricity. Thus, if whilst the unelectrified plate is laid in full and flat contact with an imperfect, and not-insulated conducting plane, it be stroked a number of times with a piece of paper, or linen, not quite damp, or with leather, and even with the naked and dry hand, or with the knob of a phial just discharged by a compleat communication between its sides, it will from thence acquire a small indeed, but sensible degree of Electricity, so that if afterwards it be taken up by its glass handle, and be presented to an electrometer, it will sensibly affect it, and sometimes it will even give a small spark if the finger is presented to it.

Mr.

Mr. VOLTA justly attributes the cause of those phenomena to the metallic plate's increased capacity for holding electric fluid, whilst it stands in flat contact with an imperfect Conductor, and to its capacity being diminished when it is separated from that contact.

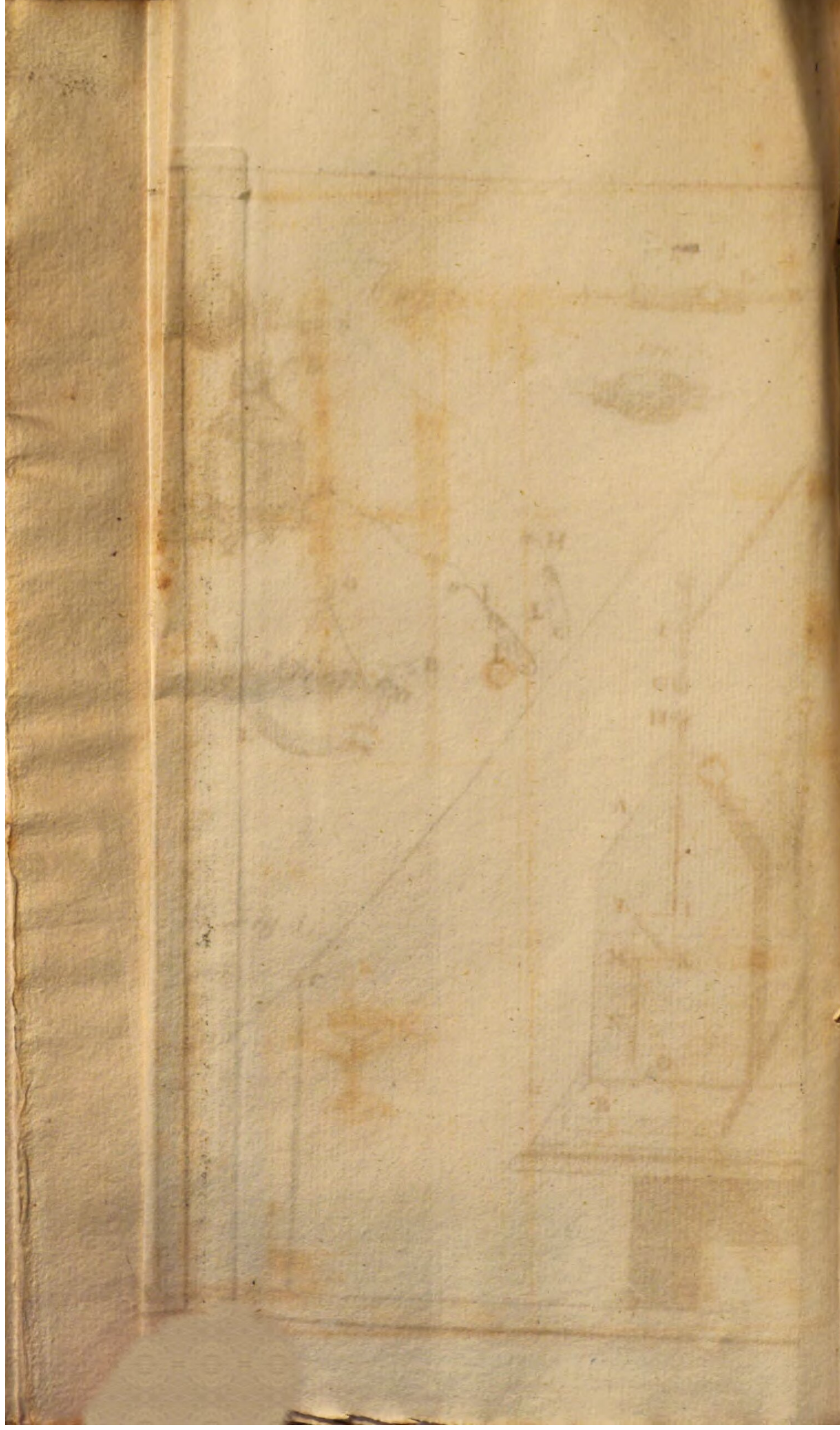
My judicious reader must easily perceive that this principle is applicable to an innumerable number of purposes; as, to the examination of the weakest atmospherical Electricity, to the excitation of imperfect electrics, &c.; it is therefore very proper for those who are anxious to distinguish themselves in Electricity, to pursue the hint, and enlarge this principle, which seems to open the easiest road to numerous and important discoveries.





T. Cavallo del.

Jn. Lodge Sculp.



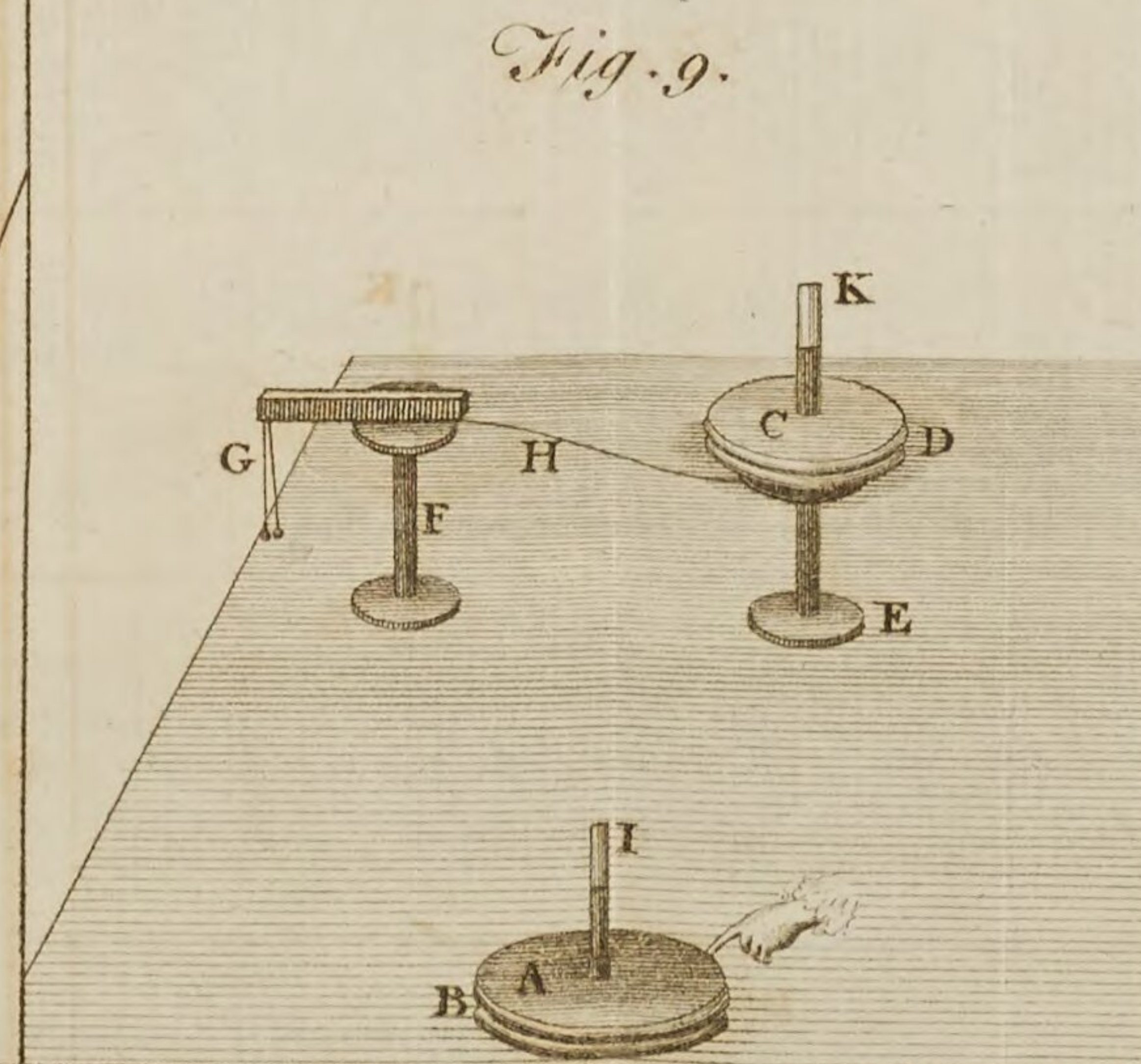
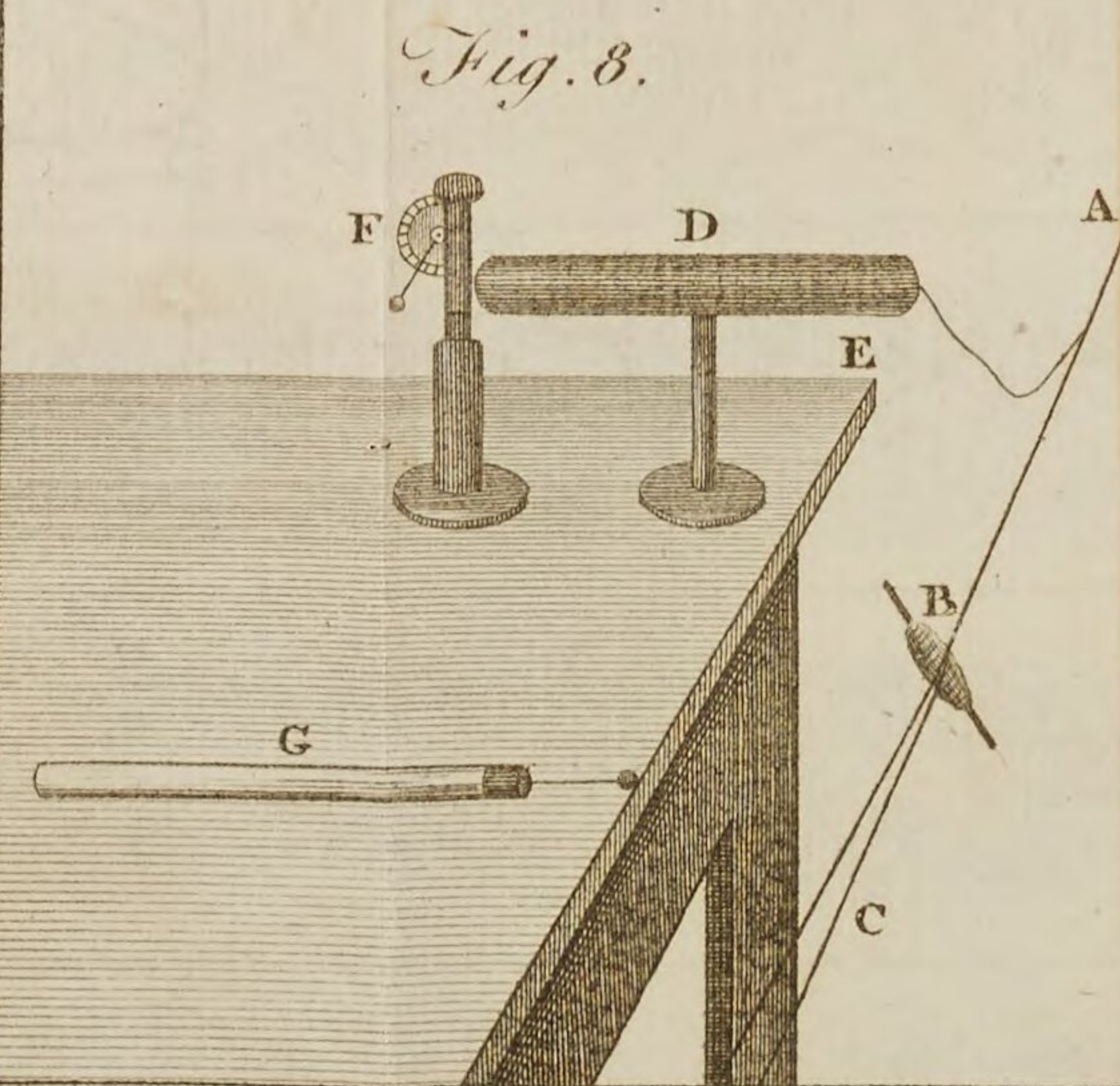
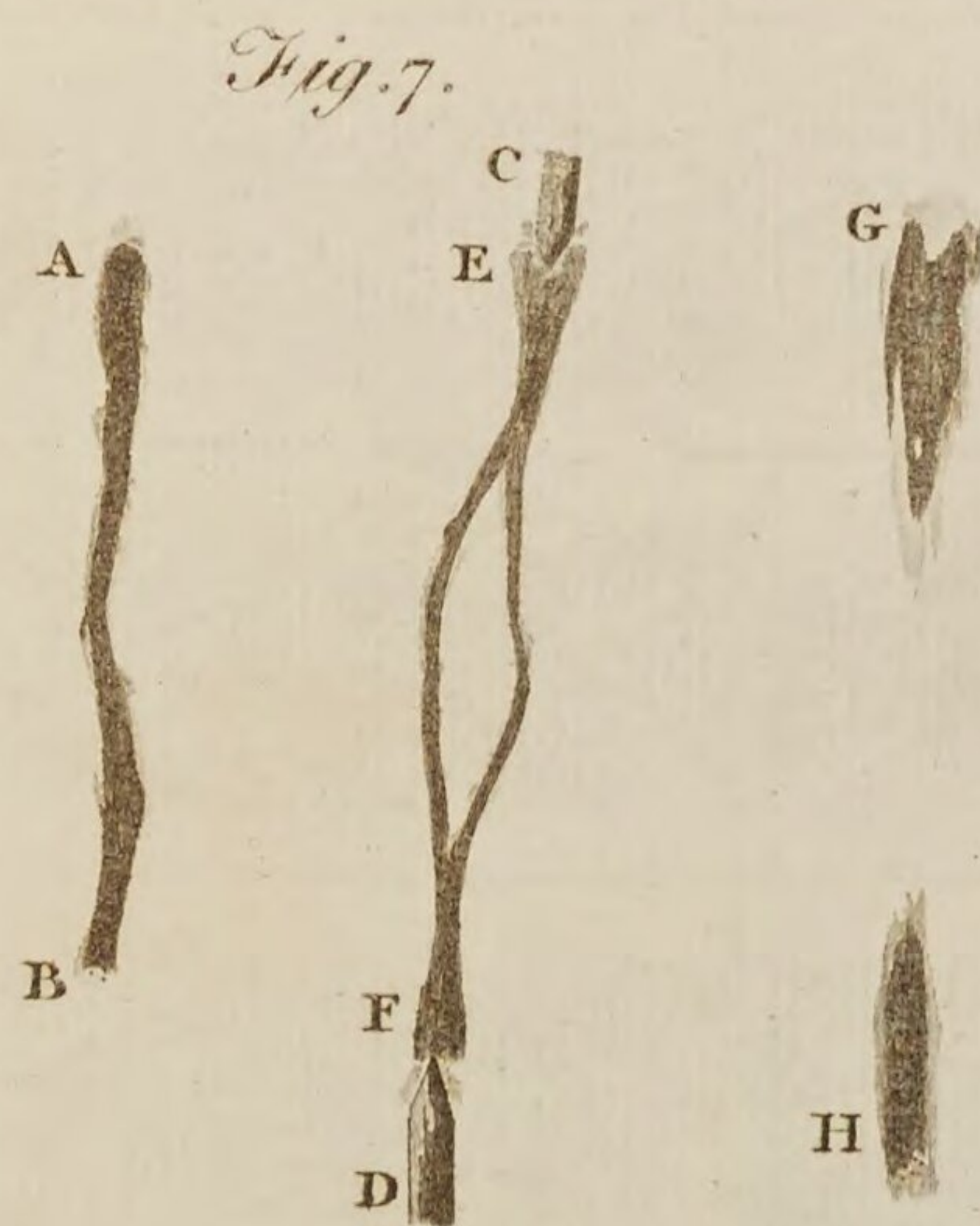
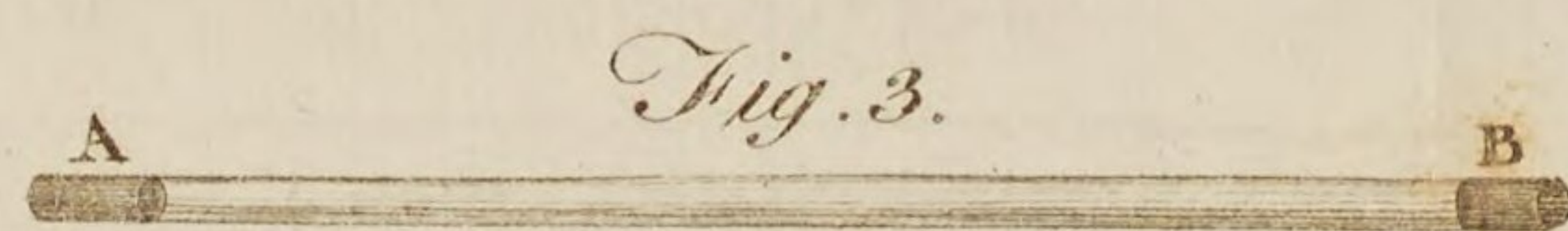
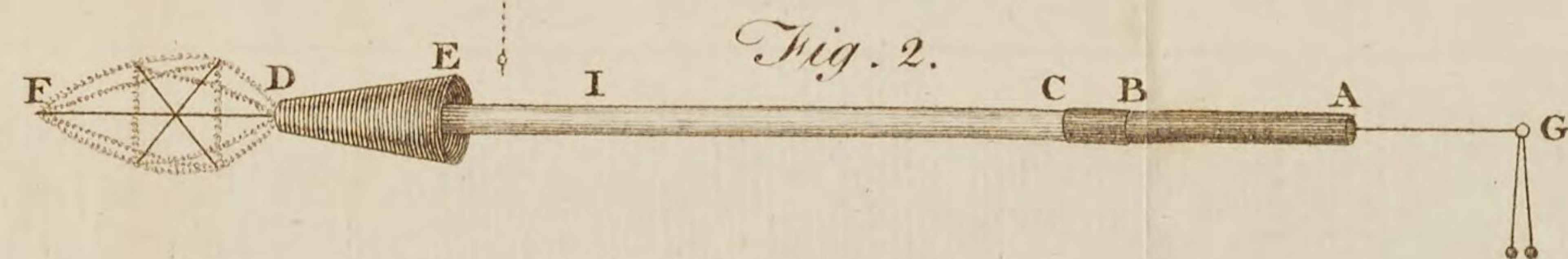


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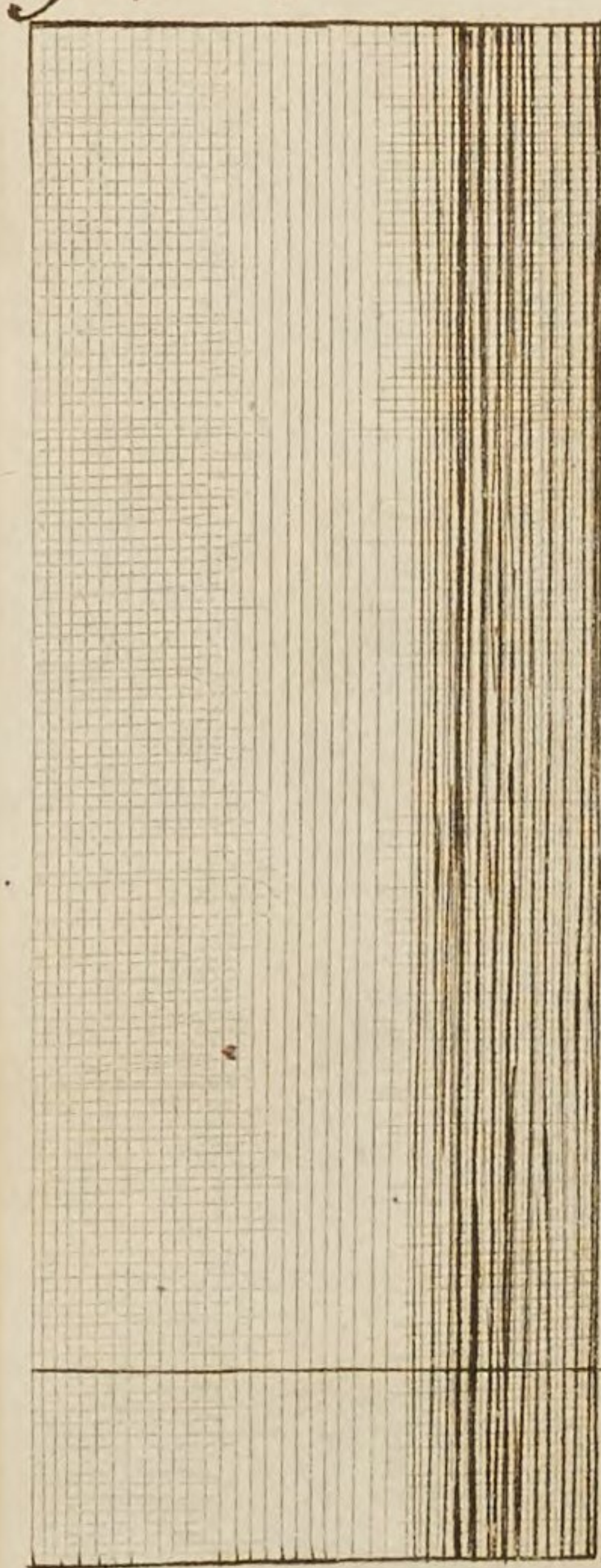


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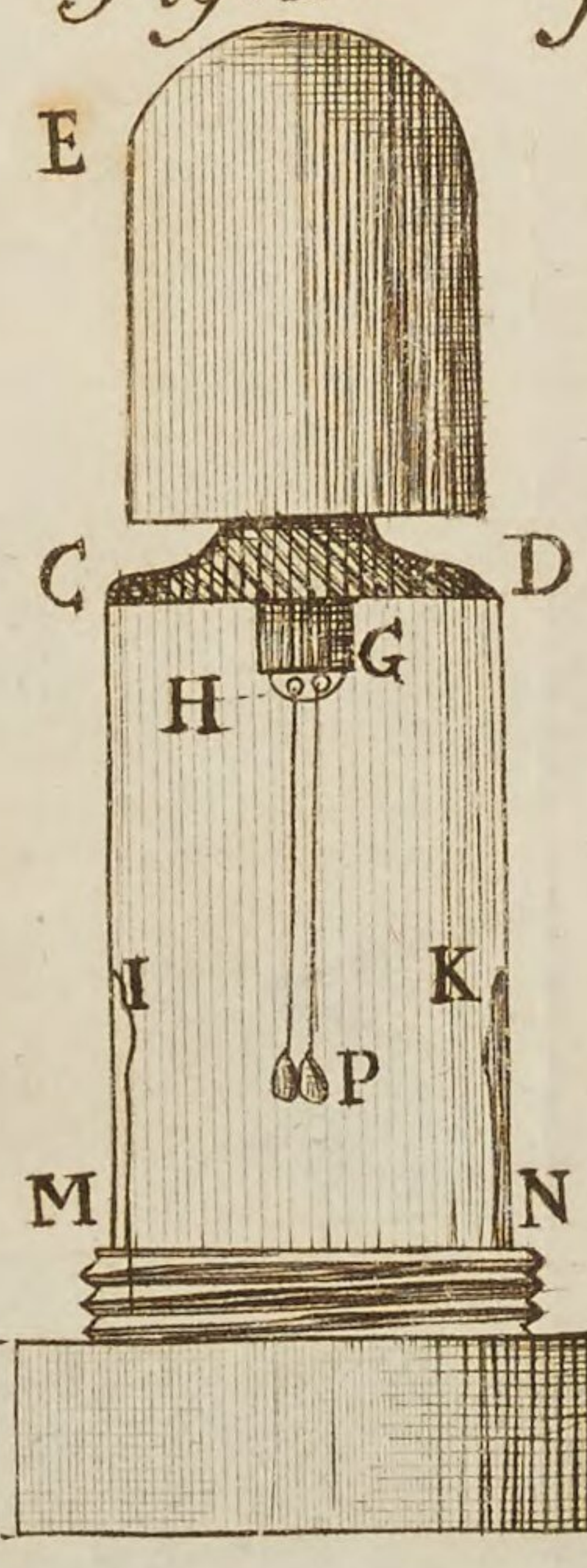


Fig. 3.

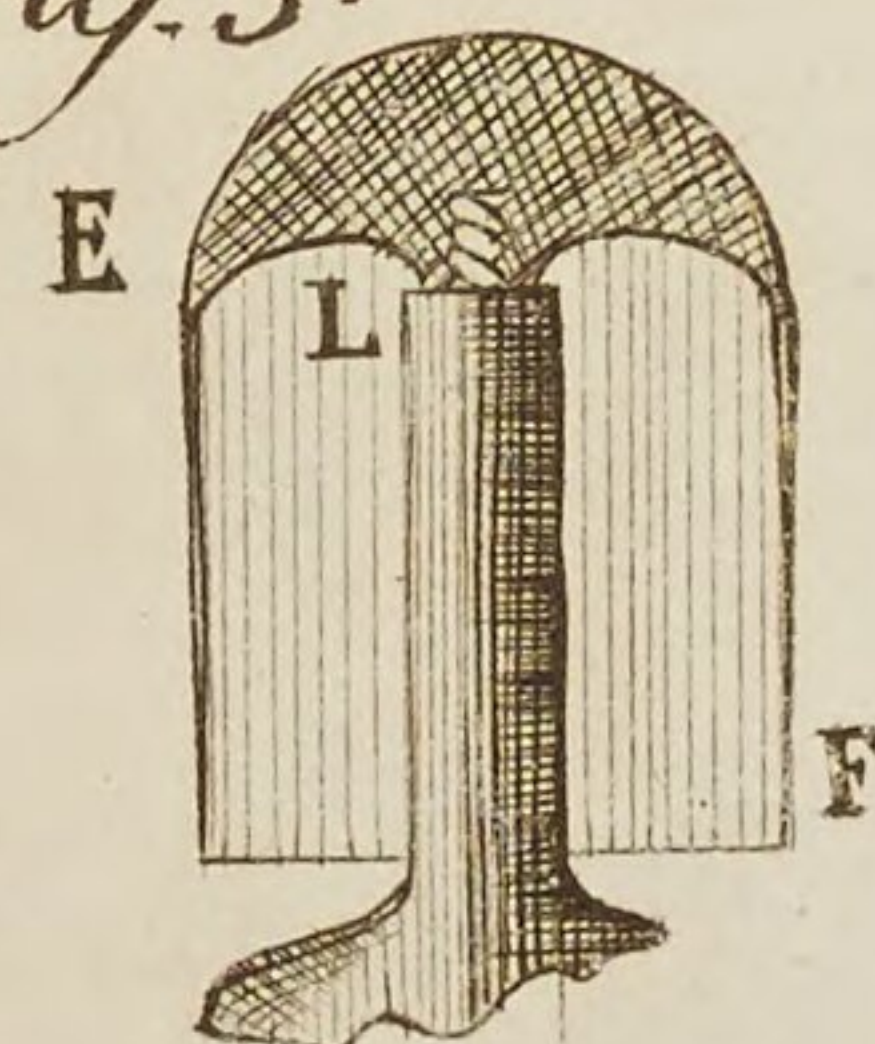


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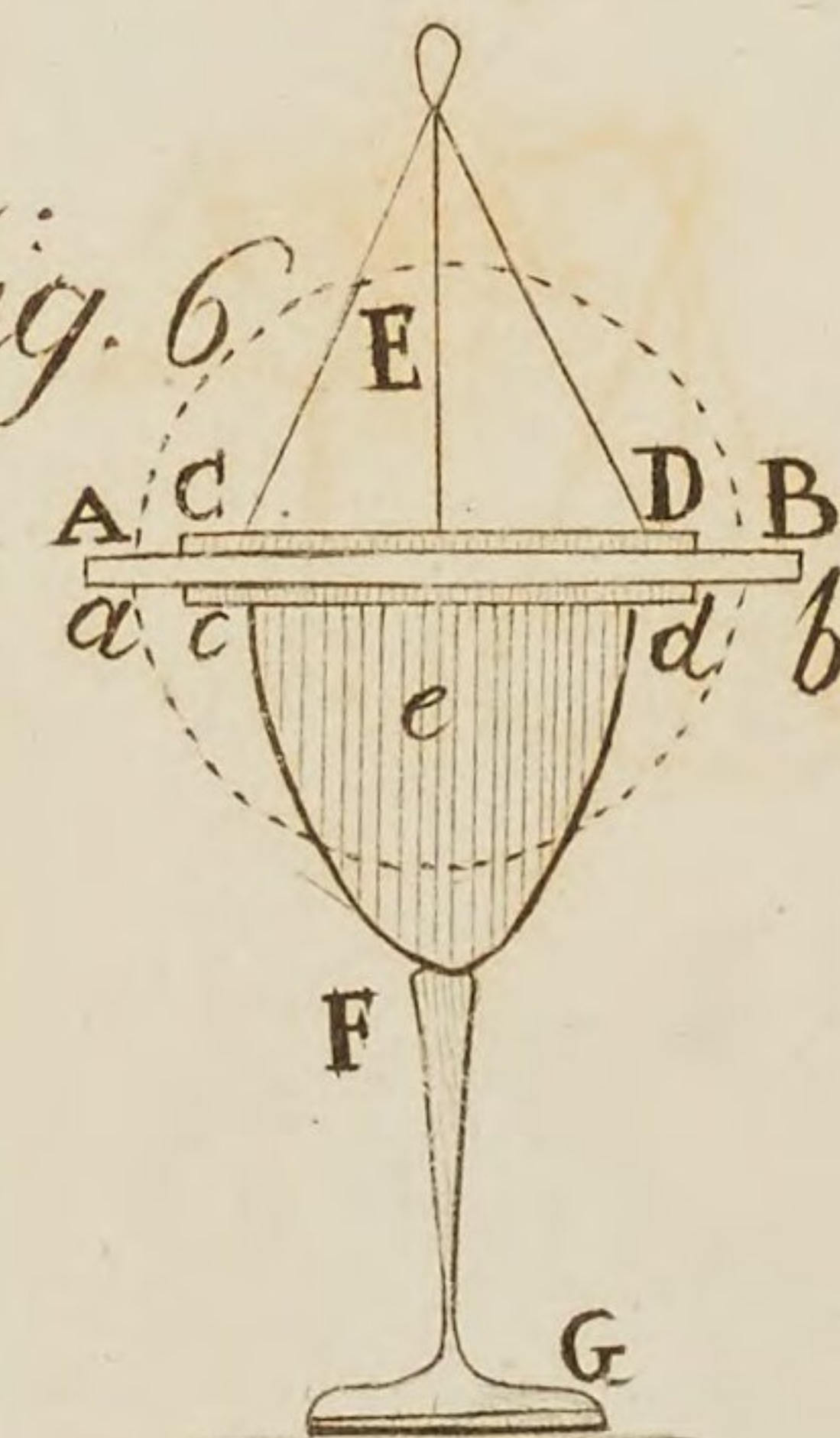


Fig. 7.



Fig. 8.

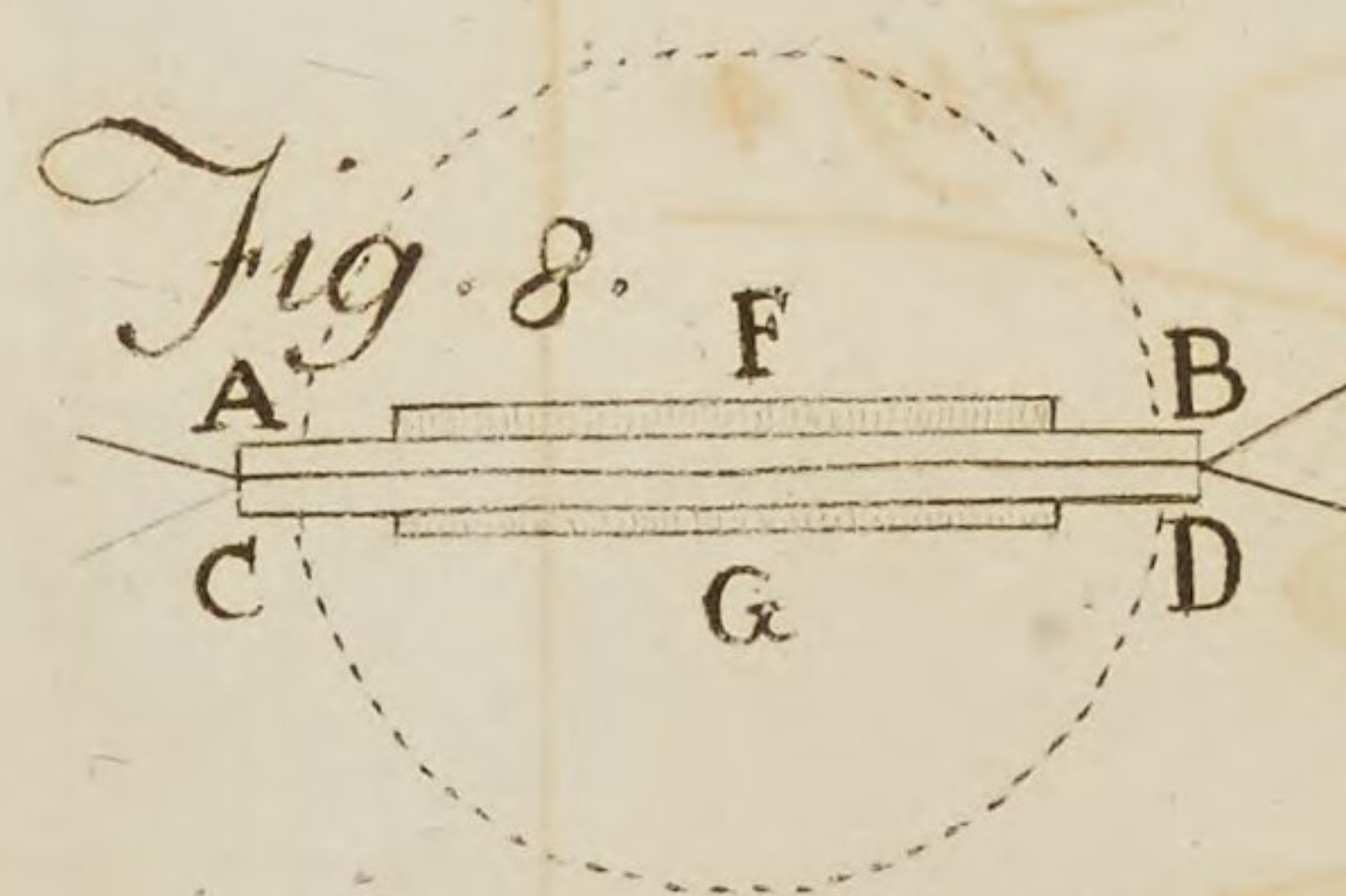


Fig. 4.

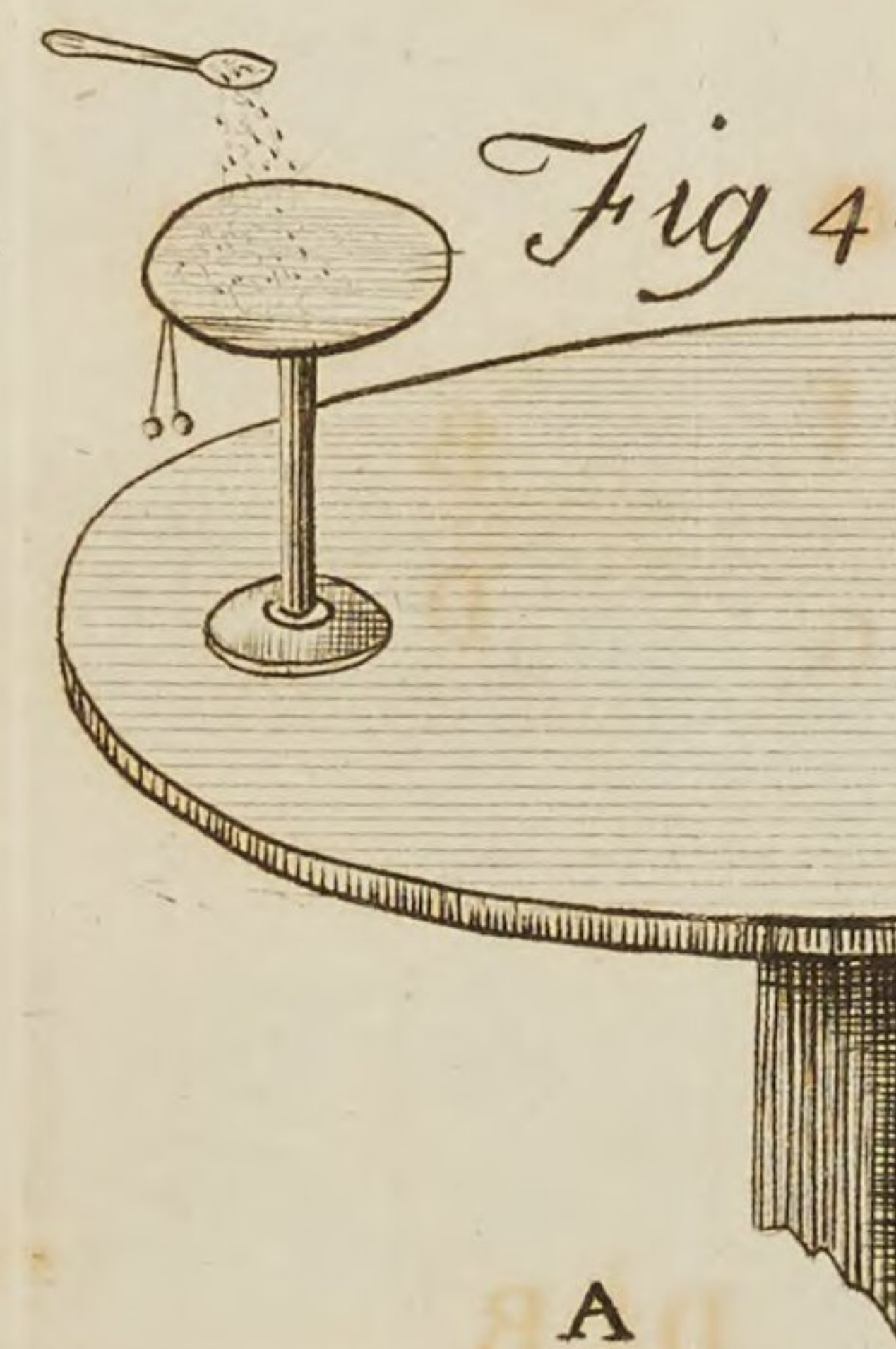
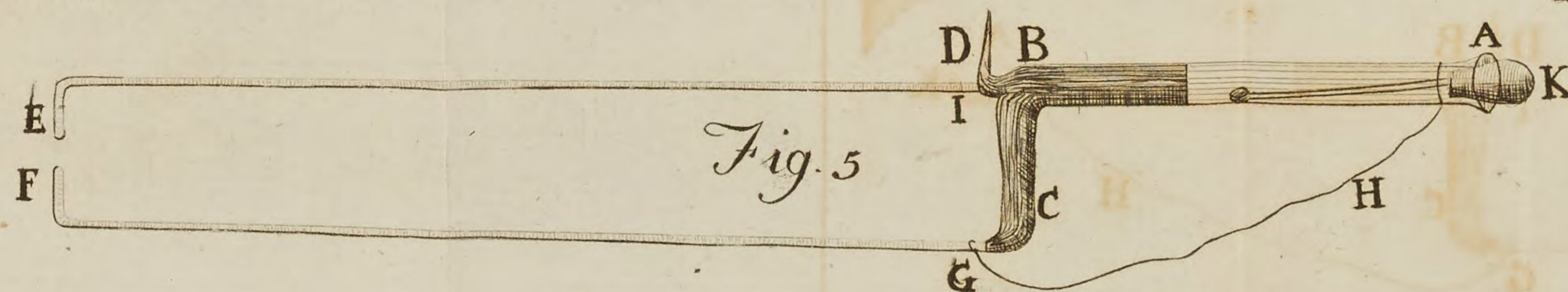


Fig. 5.



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E R R A T A.

Page 5, *between the first and second lines read, Of Electrics and Conductors.*

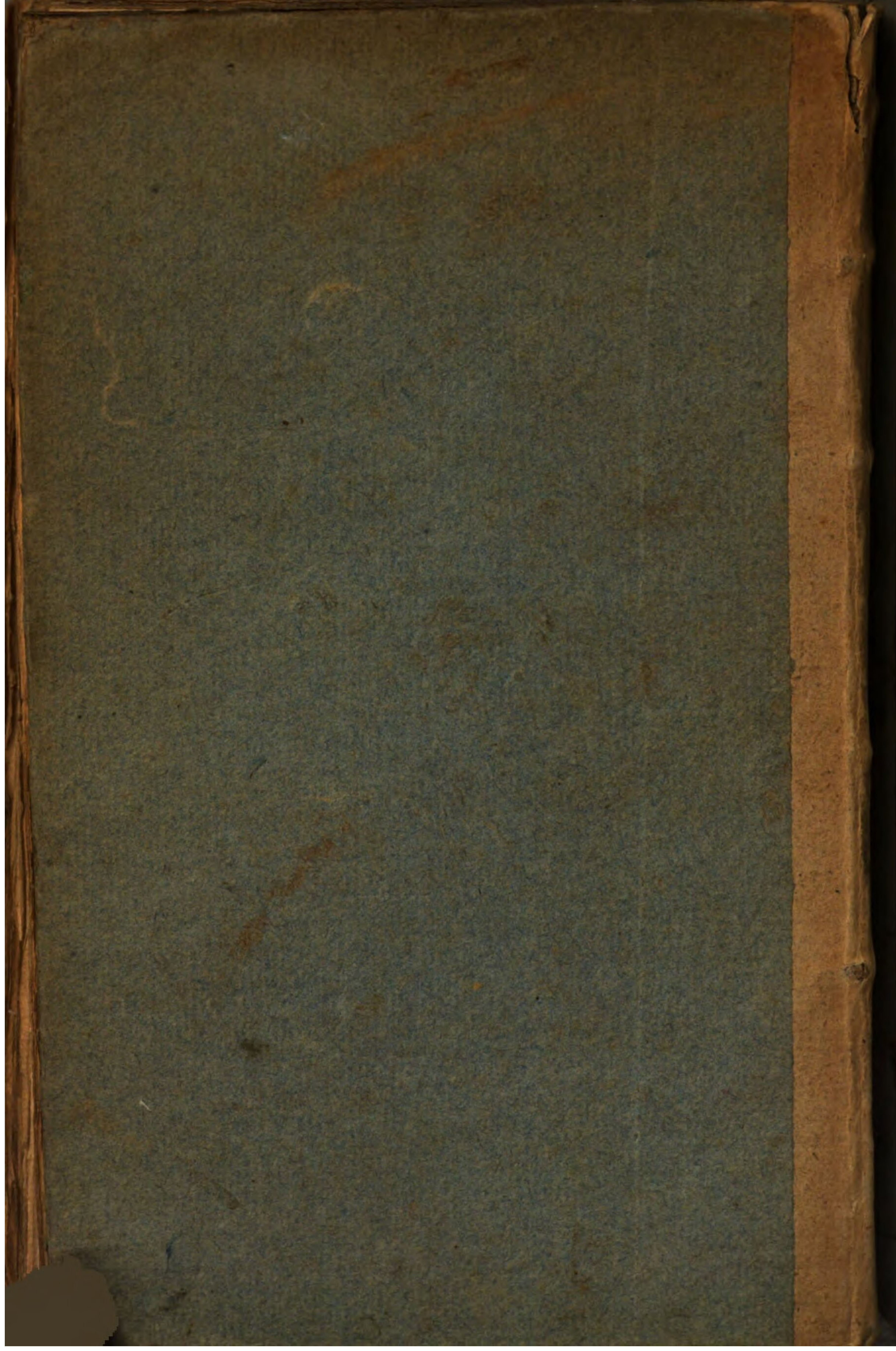
- 116, line 22, *for whenever, read wherever.*
- 151, 25, *for RINNERSLEY, read KINNERSLEY.*
- 158, 8, *for numbe ro frubbers, read number of rubbers.*
- 168, 14, *for of, read with.*
- 228, 12, *for W., read J.*
- 282, 12, *for pressies, read passies.*
- 286, 20, *for insulate, read coat.*
- 396, last, *for twice read twine.*
- 434, 9, *for the annexed drawing, read Plate IV.*
- 439, 5, *for act, read acts.*
- 468, 12, *for viz. I. A, read viz. A.*
- 493, 12, *for insulated, read uninsulated.*

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